PugetSoundPartnership

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DISCUSSION PAPER

WATER QUANTITY TOPIC FORUM

JULY 11, 2008

Puget Sound Partnership

Introduction to the Topic Forum Discussion Papers

As part of the development of the 2020 Action Agenda, six topic forum discussion papers were prepared to provoke and inspire enduring community conversation and critical thinking about the specific problems facing Puget Sound, and the strategies and actions needed to overcome the threats we face. The information from the topic forums was used to help answer two of the four questions of the Action Agenda: a) What is the status of Puget Sound's health and what are the biggest threats to it?; and b) What actions should be taken that will move use from where we are today to a healthy Puget Sound by 2020?

The papers represent the first effort in the region to comprehensively synthesize and document what we know about the Sound's problems, solutions that work, our current approach to solving problems, and what approaches we need to continue, add, or change. These papers address broad science and policy questions, providing an overview of each topic that looks at the Puget Sound ecosystem, from the crest of the Cascades to the Strait of Juan de Fuca, and documenting the basis of our conclusions and recommendations. They were fundamental to establishing strong connections between science and policy as we developed the 2020 Action Agenda.

For five of the topics (human health, land use and habitat, species and biodiversity, water quality, and freshwater quantity), the Partnership commissioned small groups of science and policy experts to prepare a draft discussion paper as a starting point. The papers are organized to logically step through three initial questions (two are science and one is policy) that build to a rational conclusion (the fourth question) about the strategies and actions that we will need to continue, add, or change as a region. The design is intentional so that 1) our policies are based on science and 2) scientists and policy experts talk to one another. The intent of papers is to focus on identifying problems and solutions, rather than specific details about implementation.

The authors were instructed to review available information and prepare a brief overview of the key issues pertaining to each topic. The draft papers were produced in March 2008, reviewed by a broad audience, and discussed at individual topic forums held in April and May 2008. More than 500 people attended the topic forums, and dozens more provided comments online. During the review period, more than 1,200 pages of public comment were received from 229 people or entities. The Partnership, in conjunction with the papers' authors, reviewed and considered all of the comments as we prepared these revised discussion papers. Summarized comments and responses are included as appendices to the papers.

Following this public process, the Partnership Science Panel conducted a peer review of the five papers focused only on the science questions. The peer review addressed: 1) Do the conclusions in the paper have strong analytical support, and what is the nature of that support (e.g., multiple lines of evidence are offered; empirical data, analyses, or model results are available; documentation of rationale underpinning key points is clear)?, 2) What are key uncertainties or gaps in understanding, and how might these be addressed in future work?, and 3) Given reviewer assessment and characterization of the certainty in the paper's content, what guidance can be offered for how this information can be fruitfully used as part of the scientific basis of the Partnership's work? The general conclusion of the Science Panel and reviewers was that the topic forum papers were a good start at synthesizing information, particularly given the time available and length of the papers. In general, future improvements could include: more thorough discussion and inclusion of some topics (particularly climate change); inclusion of more recent and pertinent peer-reviewed literature and less use of gray literature; consistency and clarification of terms; and more treatment of terrestrial ecosystems. The schedule for developing the Action Agenda in late 2008 did not allow time for revisions to topic form papers following peer review. However, the peer review summaries were evaluated by Partnership staff when considering what portions of the topic forum papers to incorporate into the Action Agenda. The Science Panel concluded that the topic forum process was useful and a version of the process should be conducted in the future.

A sixth paper on human well-being/quality of life was also prepared as a complement to the other five. This interdisciplinary topic is a very new area of work for the Puget Sound region. The paper presents a summary of the human dimensions and quality of life considerations associated with Puget Sound ecosystem recovery as articulated by the Partnership's work products developed in support of completing the 2008 Action Agenda. The human well-being paper also provides an initial human dimensions framework for moving forward.

The discussion papers are intended to be both comprehensive and brief, providing a synthesis of existing, readily available information and an initial list of recommendations for moving forward to achieve the Partnership's six main goals. Work to refine topic forum papers and to integrate the products from the respective topic forums within an ecosystem management framework will be an ongoing effort of the Partnership. In reading the discussion papers, several concepts should be considered:

- **The discussion papers provide an overview of the topic**, summarizing and synthesizing existing documentation. These papers are intended to provide a framework for future management strategies, but are not intended to address in detail all available data on the topic.
- **The Partnership identifies priority actions that are based on science.** People concerned with the future of the Puget Sound ecosystem express a wide range of opinion about the Sound's problems and suggest literally hundreds of ideas for how to solve them. This was evidenced by the broad range of opinions expressed during the topic forum process. Our continuing goal is to find reasonable consensus on the general nature and magnitude of the documented threats to Puget Sound, so that we have a better chance of prioritizing durable and effective solutions.
- **The papers mainly focus on the Sound as a whole.** We know that there are variations in information availability, type and extent of threats, and workable solutions in different parts of our region. The action area profiles in the Action Agenda help highlight local issues.
- **The discussion papers were used to develop cross-topic priorities for the Action Agenda.** A number of key themes emerged from the topic forum process and helped define priorities for management strategies and specific actions.

- **The recommendations to the Partnership in the papers represent the conclusion of the authors based on their expertise and comments received. The recommendations were considered by the Partnership, but should not be interpreted as a Partnership endorsement.** This was an intentional design of the topic forum process.
- **The papers intentionally do not focus on the need for more education/outreach, new funding strategies including creative incentives, and a coordinated monitoring and adaptive management program.** The Partnership knows that these three aspects are critical to long-term success and is using other processes to address them. That work is more fully explained in the Action Agenda. By addressing the system-wide needs, we will be able to more effectively focus the education/outreach, funding, and adaptive management and monitoring strategies.

The Partnership greatly appreciates the level of interest and participation that reviewers showed by attending topic forums and providing thorough, thoughtful comments. The comments that we received have greatly expanded and deepened the overall level of discussion, and moved our knowledge forward on these topics. We are committed to continuing this level of engagement.

WATER QUANTITY

DISCUSSION PAPER

June 30, 2008

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The following individuals are members of the Water Quantity Topic Forum Workgroup. They contributed significant time, effort and thought into the creation of this paper and presentation materials for the Water Quantity Topic Forum:

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Water Quantity Context

This Water Quantity Topic Forum Paper addresses water quantity in the Puget Sound in the context of (1) freshwater flows to the Sound, and (2) holistic management of water resources in all watersheds draining to the Sound and the adequacy of our groundwater and freshwater flows to support instream resource needs and out-of-stream beneficial uses. The paper also addresses stormwater quantity and flood control. Stormwater quality is addressed in the Water Quality paper, and the Land Use/Habitat and Water Quality papers also address stormwater management strategies as they pertain to those topics.

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Definitions

Actual evapotranspiration: The real rate of evapotranspiration from the land surface.

Adaptive management: Continual improvement of management programs, based on information collection and application of various actions over time. Adaptive management involves management that monitors the results of policies and/or management actions, and integrates this new learning, adapting policy and management actions as necessary.

Adjudication: The process where all those claiming the right to use water from a water source are joined in a single legal action to determine the rights and priorities for the use of the water.

Aquifer: A geologic stratum containing groundwater that can be withdrawn and used for human purposes.

Aquifer storage and recovery: A specific application of artificial recharge in which water is recharged to an aquifer and stored for later recovery and use.

Baseflow: The portion of streamflow that comes from groundwater.

Best management practice (BMP): The schedules of activities, prohibitions of practices, maintenance procedures, and structural and/or managerial practices, that when used singly or in combination, prevent or reduce the release of pollutants and other adverse impacts to waters of Washington State.

Bioretention: The process of biological removal of contaminants or nutrients as fluid passes through media or a biological system.

Consumptive use: Water that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from an immediate water environment (water body, surface- or ground-water source, basin).

Demand management: The purposeful and beneficial manipulation of the level and timing of water usage. Demand management deploys various techniques for conserving water and improving the efficient use of water by end users.

Desalinization: The removal of salt and other chemicals from saltwater to create freshwater.

Drawdown: Lowering of the water surface (in open channel flow), water table or piezometric surface (in groundwater flow) resulting from a withdrawal of water.

Ecosystem: The complex of a community of organisms and its environment functioning as an ecological unit.

Efficiency: Increasing the output with the same amount of input. For example, increasing irrigation efficiency would mean that there is a greater crop production from the same amount of water use.

Environmental flows: Allocations of water to sustain native species and functioning ecosystems.

Evaporation: The movement of water to the air from sources such as the soil, canopy interception, and waterbodies.

Evapotranspiration: The collective term for the processes of evaporation and plant transpiration by which water is returned to the atmosphere.

Flood: An overflow or inundation that comes from a river or any other source, including (but not limited to) streams, tides, wave action, storm drains, or excess rainfall. Any relatively high streamflow overtopping the natural or artificial banks in any reach of a stream.

Flood control: Methods or facilities for reducing flood flows and the extent of flooding.

Flood control project: A structural system installed to protect land and improvements from floods by the construction of dikes, river embankments, channels, or dams.

Floodplain: The total area subject to inundation by a flood including the flood fringe and floodway.

Gage: Device for registering precipitation, water level, discharge, velocity, pressure, temperature, etc. Also, a measure of the thickness of metal; e.g., diameter of wire, wall thickness of steel pipe.

Gaging station: A selected section of a stream channel equipped with a gage, recorder, or other facilities for determining stream discharge.

Groundwater: Water in a saturated zone or stratum beneath the land surface or a surface waterbody.

Groundwater recharge: Inflow to a groundwater reservoir.

Groundwater table: The free surface of the groundwater, that surface subject to atmospheric pressure under the ground, generally rising and falling with the season, the rate of withdrawal, the rate of restoration, and other conditions. It is seldom static.

Group A water system: Those water systems that regularly serve either 15 or more service connections or 25 or more people per day for 60 or more days per year.

Habitat: The specific area or environment in which a particular type of plant or animal lives. An organism's habitat must provide all of the basic requirements for life and should be protected from harmful biological, chemical, and physical alterations.

Impervious surface: Mainly artificial structures, such as pavements, rooftops, sidewalks, roads, and parking lots - covered by impenetrable materials such as asphalt, concrete, brick, and stone. Impervious surfaces seal the soil surface, preventing rainwater infiltration and natural groundwater recharge.

Infiltration: The downward movement of water from the surface to the subsoil.

Infiltration rate: The rate, usually expressed in inches/hour, at which water moves downward (percolates) through the soil profile. Short-term infiltration rates may be inferred from soil analysis or texture or derived from field measurements. Long-term infiltration rates are affected by variability in soils and subsurface conditions at the site, the effectiveness of pretreatment or influent control, and the degree of long-term maintenance of the infiltration facility.

Low Impact Development: A stormwater management and land development strategy applied at the parcel and subdivision scale that emphasizes conservation and use of on-site natural features integrated with engineered small-scale hydrologic controls to more closely mimic pre-development hydrologic functions.

National Pollutant Discharge Elimination System (NPDES): The part of the federal Clean Water Act, which requires point source dischargers to obtain permits. These permits are referred to as NPDES permits and, in Washington State, are administered by the Washington State Department of Ecology.

Peak discharge or peak flow: The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

Permit-exempt: Wells that do not require a permit from the Washington State Department of Ecology and are generally used for domestic purposes, including stock water and small-scale irrigation.

Perviousness: Related to the size and continuity of void spaces in soils; related to a soil's infiltration rate.

Prior appropriation doctrine: This doctrine, also known as "first in time, first in right," means that the most senior right in the basin is entitled to its entire quantity of water before the second most senior right receives any water. Those who first put water to beneficial use have seniority in access to water over others when shortages occur. This strict seniority system continues down to the most junior right in the basin and, in times of drought, junior water right holders may not get their allotment of water.

Puget Sound basin: Puget Sound south of Admiralty Inlet (including Hood Canal and Saratoga Passage); the waters north to the Canadian border, including portions of the Strait of Georgia; the Strait of Juan de Fuca south of the Canadian border; and all the lands draining into these waters as mapped in Water Resources Inventory Areas numbers 1 through 19, set forth in WAC 173-500-040.

Rainwater Harvest: The gathering, or accumulating and storing, of rainwater.

Recharge: The addition of water to the zone of saturation (i.e., an aquifer).

Reclaimed water: Former wastewater (sewage) that has been treated to remove solids and certain impurities, and then used for nonpotable uses, such as irrigation, dust control, fire suppression and recharge.

Reservation: Water that is reserved for future out-of-stream use and exempt from instream flow requirements.

Restoration: Actions performed to reestablish wetland functional characteristics and processes that have been lost by alterations, activities, or catastrophic events in an area that no longer meets the definition of a wetland.

Runoff: Water originating from rainfall and other precipitation that is found in drainage facilities, rivers, streams, springs, seeps, ponds, lakes and wetlands as well as shallow groundwater. As applied in this manual, it also means the portion of rainfall or other precipitation that becomes surface flow and interflow.

Salmonid: A member of the fish family Salmonidae. Chinook, coho, chum, sockeye and pink salmon; cutthroat, brook, brown, rainbow, and steelhead trout; Dolly Varden, kokanee, and char are examples of salmonid species.

Scour: Erosion of channel banks due to excessive velocity of the flow of surface and stormwater runoff.

Sill: A submerged ridge at relatively shallow depth separating the basins of two bodies of water.

Source exchange: Use of an alternate source of water supply to reduce, discontinue, or temporarily rest an existing source of water supply.

Stormwater: That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, pipes and other features of a stormwater drainage system into a defined surface waterbody, or a constructed infiltration facility.

Streams: Those areas where surface waters flow sufficiently to produce a defined channel or bed. A defined channel or bed is an area that demonstrates clear evidence of the passage of water and includes, but is not limited to, indicated by hydraulically sorted sediments or the removal of vegetative litter or loosely rooted vegetation by the action of moving water. The channel or bed need not contain water yearround.

Streamflow augmentation: Using groundwater to increase streamflows.

Water market: An institutional mechanism that facilitates the legal transfer and market exchange of surface water, groundwater, or water storage. This mechanism may be administered by any type of entity, such as private, public, or non-profit.

Water right certificate: The legal record of a water right issued by Washington State Department of Ecology once the department confirms that all the conditions of the permit have been met. It is recorded at a county auditor's office. Once Ecology issues a certificate, the water right is considered appurtenant (attached) to the land on which the water is used. (http://www.ecy.wa.gov/pubs/961804swr.pdf)

Water right claim: A claim to a water right, for a water use that predates the state's water permitting system (for surface water, 1917/1932, for groundwater, 1945). The validity of a claim can only be confirmed through judicial processes. (http://www.ecy.wa.gov/pubs/961804swr.pdf)

Water right permit: Permission by the state to develop a water right; it is not a final water right. A permit allows you to proceed with construction of the water system and start putting the water to beneficial use, in accordance with the terms of your permit. (http://www.ecy.wa.gov/pubs/961804swr.pdf)

Watershed: The land area that drains into the defined waterbody.

Wetlands: Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

Science Question 1 (S1):

Status of Freshwater Quantity in the Puget Sound Region

A. *Where in the Puget Sound region are the amount, timing, and distribution of freshwater flows adequate? Where are they impaired?*

Freshwater Inflows to Puget Sound

To date, no regional summary exists of the adequacy of freshwater resources in the Puget Sound basin. From an ecosystem viewpoint, we know that the flow regime of a river is a major factor in determining long-term aquatic ecosystem health and sustainability both in upland areas and in estuarine, nearshore, and marine environments. Numerous studies have documented the central role of naturally varying water flows, including day-to-day and seasonal variations, in maintaining the health of rivers, floodplains, and estuaries (Arthington et al. 1992, Walker et al., 1995, Sparks, 1995, Poff et al., 1997, Bunn and Arthington, 2002). The full range of natural flow variation (ranging from baseflows to high-flow pulses and floods) and the timing and duration of those flows play important ecological roles in river and estuarine ecosystems (Postel and Richter, 2003).

Flows of freshwater into estuaries have an important effect on aquatic food webs and the habitats found in estuarine and nearshore areas (Olsen et al., 2006). Freshwater inflows deliver nutrients and sediments to estuaries and affect salinity levels and water circulation. In addition to surface flows, groundwater flows can also influence the flow of freshwater into estuaries and marine environments in areas where groundwater is hydrologically connected to these habitats. Together, these natural hydrologic regimes sustain native species and ecosystems that benefit human populations (Postel and Richter, 2003, Olsen et al., 2006).

The effect of freshwater flows on Puget Sound is complex and although a detailed discussion of all the effects is beyond the scope of this paper, major factors include:

- There are two major periods of freshwater runoff into Puget Sound: Peak flows occur in December and June (Ruckelshaus and McClure, 2007). However, the timing of peak flow events varies in different sub-regions. For example, gaging data indicate that peak flow events have occurred in low elevation river basins in mid-Puget Sound between November and February (U.S. Geological Survey (USGS), 2008a and USGS, 2008b).

- The Skagit and Snohomish watersheds in the Whidbey Basin are the major sources of freshwater from Puget Sound river systems (Figure S1-1). However, total annual freshwater inputs to the Puget Sound are only 10-20% of the amount of freshwater entering the Strait of Georgia, primarily through the Fraser River (Gustafson et al., 2000).

- Total annual inflow to the Puget Sound declined 13 percent between 1948 and 2003; much of which can be attributed to decreases in precipitation (Snover et al., 2005). Furthermore, the fraction of annual freshwater flow entering Puget Sound in June through September decreased by 18 percent during the same period of time (Snover et al., 2005), indicating that flow rates during low flow periods are declining relative to total annual flow volumes. Causes of diminished freshwater flows during low flow periods likely include decreased precipitation, land use, regulation of flows and warming (Snover et al., 2005)[1].

[1] Streamflow data used in this analysis include the following rivers, in descending order of volume: the Snohomish, Puyallup, Nooksack, Nisqually, Green, Stillaguamish, Skokomish, Cedar, Deschutes, Samish, and Duckabush. The Skagit is omitted even though it is the largest because of the effects on flow of the operation of Ross and Diablo dams for hydropower. The Nisqually, Deschutes and Samish are omitted because of incomplete flow records.

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Policy Question 2 (P2):

What *Needs to be Done* to Address Threats to Freshwater Resources in the Puget Sound Region?

Potential policy approaches to address documented threats to freshwater resources (surface and groundwater) in the Puget Sound region, for habitat, species, and human water supply.

This discussion builds on the information presented in the responses to questions S1 and S2, and P1, to provide recommendations and conclusions that are supported by science and data.

A. Problem statement

Surface water flows and groundwater levels in the Puget Sound region have been modified through:

- Water withdrawals from rivers, streams, and aquifers for municipal, domestic, commercial, industrial, and agriculture water supplies;
- Land use practices that increase impervious surfaces and/or decrease native vegetation and result in reduced groundwater recharge, higher peak flows, and earlier and sustained low flows (baseflows).
- Seawater intrusion of coastal aquifers;
- Channel modifications, including dams and levees; and
- Loss of wetlands and floodplains.

Low streamflows and peak stormwater events impact many rivers and streams in the Puget Sound region (Shared Strategy, 2007; PSP, 2006, Currens et al., 2002). Collectively, these changes can contribute to:

- Degradation of aquatic habitat,
- Reductions in the abundance, viability, and diversity of native species (Annear, et al., 2004; Beecher, 1990; IFC, 2008; Smoker, 1953, 1955; Matthews and Olson, 1980; Zillges, 1977); and
- Uncertainty in providing water supply for human uses and growing populations (San Juan County WRMC, 2005; Island County WRMC, 2005; Nisqually Indian Tribe, 2003; WRIA 1 Watershed Planning Unit, 2005; Cascadia Consulting Group, 2007; HDR Engineering, 2007).

With a projected human population of 5.2 million people by 2020, along with concurrent land use changes, existing water management approaches will make it difficult to provide enough water to support native aquatic species while accommodating community growth in the Puget Sound region. Climate change will likely compound these effects.

B. What strategies are working?

Several existing strategies discussed in response to question P1 appear to be effective in meeting their goals and addressing some threats to freshwater supply:

a. Demand management opportunities, such as increased conservation and use of reclaimed water, graywater and rainwater have been shown to have the potential to significantly decrease per capita water consumption. This can help offset increased use due to population growth and exacerbation of impacts due to climate trends.
b. More recent instream flow rules, promulgated since 2000, provide tools to address threats to instream needs resulting from future consumptive use due to growth, and link land use to water use.

c. Streamflow restoration options associated with dam operations address some flow impairment and instream needs.
d. Other supply side strategies including source exchange, aquifer storage and recovery, and water marketing (including leases, trusts and purchase) may be useful in putting water in streams during times when flow impairment is most limiting.

C. What strategies are not working?

Some strategies discussed in the response to question P1 are either absent or ineffective at addressing:

a. Conservation at a regional level (although there are some locally successful programs);
b. The alteration of hydrologic and geomorphic processes caused by land development and clearing;
c. Proliferation of permit-exempt wells;
d. Defining the extent and validity of water right claims, permits, and certificates;
e. Coordination or integration among water quantity plans at the regional level;
f. Enforcement of the water code;
g. The adequacy of flows to support estuarine, nearshore, and marine health; and
h. Monitoring of seawater intrusion.

In some cases, strategies are ineffective due to lack of consistent and stable funding mechanisms or lack of ongoing monitoring (that is often curtailed due to insufficient funding).

D. Key Themes for Strategy Development

The Puget Sound Partnership is developing initial strategies for addressing water quantity issues in the Puget Sound region. Strategies addressing overcommitment of freshwater resources, impacts of stormwater runoff on watershed hydrology, projected increases in water demand, future instream and out-of-stream needs, and the potential effects of climate change are presented below. The Land Use Topic Forum is also addressing strategies related to threats associated with land use practices, including increased impervious surfaces, reduced groundwater recharge, and loss of wetlands. The Water Quality Topic Forum is addressing strategies related to stormwater runoff quality. The linkage between these topics demonstrates the need for an integrated approach to land use, watershed, stormwater, water quality, water supply, and Endangered Species Act (ESA) recovery planning and implementation.

The Water Quantity Core Workgroup has developed four priority water quantity strategies, and associated actions, for inclusion in the full ecosystem synthesis for the Puget Sound Partnership's Action Agenda. The order of these strategies does not indicate priority:

Key Water Quantity Strategies:

- Integrated, Ecosystem Approach to Environmental Management and Planning in Puget Sound
- Conservation/Demand Management
- Protect and Enhance Instream Flows
- Stormwater Quantity Management

E. Strategies and associated actions between 2008 and 2020

The proposed actions presented below, by key strategy, are intended to be integrated into a broad, regional planning approach that provides the flexibility to consider local, site-specific and season specific conditions during implementation, and distinguishes between rural and urban environmental stressors. Some of the strategies below are already required or authorized under state law, but they have not been fully implemented for a number of reasons.

Each of the numbered strategies listed below is followed by proposed actions that are intended to lead to a healthy Puget Sound by 2020 (Puget Sound Partnership, 2008). To be successful in meeting their intended outcomes, these actions involve commitments by resource agencies, local governments, and water suppliers, as well as a general change in public expectations and behaviors related to water use. The actions have been denoted as "immediate," "short-term," or "long-term." Timing issues are discussed in the next section.

Strategy 1: Address policy linkages that enable an integrated Ecosystem Approach to Environmental Planning in Puget Sound.

Despite the large number of programs that involve some aspect of water quantity, the Puget Sound region does not have policies that address threats from an ecosystem perspective. Current approaches to streamflows, water use, land use, and stormwater management are fragmented. Integration of these elements will require a fundamental realignment of policy and regulation at the state level. This recommendation is not intended to suggest the addition of another layer of organization, but rather, to fix or reorganize institutions such that they can effectively achieve goals from an ecosystem perspective. Integrating these fragmented planning efforts will increase complexity, and could hinder progress in the short-term. However, in the longer term, integration of water-related planning efforts is the only way to begin to restore natural hydrologic processes and associated habitats to watersheds of Puget Sound.

There is a need to further evaluate and identify ecosystem-wide, integrated management programs. The actions below begin to address this need.

Proposed Actions:

1a. Develop a process and organizational structure to integrate land use planning, watershed planning, water quality planning, utility planning (including stormwater and water supply) and ESA recovery planning. (Immediate)

- An ecosystem approach to management should link stormwater management (and some aspects of wastewater management including reclaimed water), water supply, land use, species recovery, and riparian zone management (including shoreline management). This will cross the boundaries of water quality, water quantity and land use topics.
- This effort also supports decreased pollutant loading to Puget Sound by integrating land use and watershed planning, stormwater basin plans, structural retrofits, and Total Maximum Daily Load studies (TMDLs) where water quality impairment is related to flow.

1b. Consider instream flow needs during planning and permitting for stormwater and reclaimed water infrastructure. (Long-term)

Explore decentralized treatment that results in distributed systems (stormwater, wastewater, reclaimed water) that essentially return water at the point (or near the point) of withdrawal as a way to begin to restore the natural hydrology of watersheds in Puget Sound. Groundwater quality impacts associated with this type of approach must also be understood to characterize overall effectiveness and risk.

1c. Complete the task within the Puget Sound Salmon Recovery Plan for the development and implementation of comprehensive basin flow protection and enhancement programs (PEPS). (Short-term)[25]

- Define the basic elements of a PEP and develop an initial checklist: consider watershed processes, land use and resulting stormwater processes, instream habitat needs and water supply, demand and reuse.
- Provide technical assistance and incentives for the development of PEPs in each WRIA.
- Identify the tools necessary for streamflow restoration and a tailored strategic approach for applying these tools in each watershed.
- Develop benchmarks and performance measures.

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[25] Note that Proposed Action 1c is also a component of Strategy 3: "Protect and Enhance Instream Flows through Flow Targets linked to Fish Habitat Needs". It is listed under Strategy 1 because these PEPs (comprehensive basin flow protection and enhancement programs) could be used to provide the structure to integrate ecosystem elements at a basin (or watershed – WRIA) scale.

Strategy 2: Promote Demand Management: identify water needs or goals for people by watershed (WRIA) and develop conservation and reuse.

Proposed Actions:

2a. Promote sustainable water use practices through regulations and incentives addressing water use efficiency, use of reclaimed water (including graywater and rainwater), and storage. (Immediate)

- Recognize and support businesses with sustainable water use practices.
- Build additional accountability around water use at the individual, corporate, and government levels, including utility supply, demand, conservation and pricing.
- Create and implement water use efficiency rules for all sectors of use; consider differing levels of economic investment required by sector.
- Develop rules for rainwater and graywater use and water reclamation that promote water conservation.
- Implement innovative water storage projects such as aquifer storage and recovery.
- Expand financial support and incentives for capital investments in rainwater, graywater, and water reclamation projects, particularly where there are willing partners and demonstrable environmental benefits.
- Identify and address barriers to the use of rainwater, graywater and reclaimed water.

2b. Conduct a regionally consistent assessment of water use and future water needs, and availability. (Long-term)

- Estimate the quantity of ground and surface water use and future water availability by watershed (WRIA) or regional management area (action area) in the Puget Sound region. Integrate this information in reclaimed-water planning and stormwater planning.
- Develop an integrated and regionally accessible groundwater monitoring program (including some targeted streamflow monitoring) and associated database.

2c. Perform outreach and education to address human expectations about water use. (Immediate)

Conduct a rigorous, regional conservation program that is specifically designed to address human expectations with respect to water availability and use. Increase the public understanding of how decisions about daily water use affect streams and aquatic ecosystems. A significant shift in social behaviors is needed to reduce current per capita water use.

Strategy 3: Protect and Enhance Instream Flows through Flow Targets linked to Fish Habitat Needs (includes compliance and enforcement)

Proposed Actions (See also 1c):

3a. Establish instream flows in Puget Sound basins without flow rules. (Immediate)

These include the Samish (WRIA 3), Skokomish-Dosewallips (WRIA 16), Quilcene-Snow (WRIA 17), Elwha-Dungeness (WRIA 18), and Lyre-Hoko (WRIA 19). Consider maintenance of groundwater levels, basin closures, limitations on the cumulative impact of exempt wells, and adequacy of flows to support estuarine function where applicable.

3b. Update instream flow rules that were adopted prior to 1986. (Short-term)

The science for assessing instream flow needs and our understanding of aquatic habitat and flow relationships has improved substantially since adoption of these earlier rules. Older rules did not include provisions for permit-exempt groundwater management, water reserves for future consumptive use, and determination of seasonal and year-round closures. It is these management tools that make instream flow rule-making effective at managing impacts of human water use and allocation.

3c. Identify flow limitations and targets for fish as part of Salmon Recovery Plan implementation. (Immediate)

- Develop WRIA-based inventories to determine where low- and high-flow problems occur.
- Assess the adequacy/nature of streamflows and healthy estuaries.
- Establish the relationship between flows and viable salmonid populations (VSPs).
- Identify salmonid recovery flow targets (consider non-salmonids where possible).

This work should be coordinated with the state effort to set instream flows, salmon recovery planning, and the 2020 Action Agenda as a whole.

3d. Consider regulation of exempt wells by general permit, either statewide, by WRIA, or by region (e.g., Puget Sound region). (Immediate)

3e. Develop water use compliance and enforcement plans in each Puget Sound watershed. (Immediate)
Compliance and enforcement plans need to be coordinated with local watershed planning efforts (where planning is occurring). Compliance and enforcement plans should include a prioritized list of actions, associated budget estimates, and an implementation schedule.

3f. Establish water masters for each basin to ensure compliance with water code. (Short-term)
Water masters control the use of water within a specific district to which they are assigned, and can help to address the illegal use of water.

3g. Require metering and reporting for 80 percent of water use (by volume) in all watersheds. (Immediate)
Begin with "fish critical" Puget Sound watersheds (Nooksack, Snohomish, Cedar/Sammamish, Duwamish/Green, Puyallup/White, Chambers/Clover, Quilcene/Snow, and Elwha/Dungeness). Create a web-enabled database for metering data.

3h. Assess the adequacy of flows for estuarine and nearshore marine habitat including channel morphology and flows, salinity levels, and circulation. (Long-term)
Determine the range of freshwater inputs necessary to maintain healthy estuarine and marine nearshore habitats in Puget Sound. Assess total freshwater inputs to Puget Sound and trends in low- and high-flow inputs over time.

3i. Address groundwater management (including monitoring) in the Puget Sound region to protect streamflow. (Immediate)

3j. Identify benchmarks for flow improvements and evaluate them. (Short-term)
Analyze streamflow trends for all of the major tributaries to Puget Sound and compare to instream flows set by rule. Identify metrics that indicate the benefits of flow improvements. Quantify those benefits for individual species. Collect the data that will quantify the benefits of flow improvements for individual species.

Strategy 4: More Effectively Manage Stormwater Quantity to Address Alteration of Watershed Processes Caused by Land Development and Clearing.

Proposed Actions:

4a. Increase the use of innovative stormwater management practices that protect and restore hydrologic processes to support low flows and aquifer recharge. (Immediate)

- Develop standards for baseflow maintenance and include those standards in the Western Washington Stormwater Manual. Consider LID techniques for new growth and structural retrofit for existing development.
- Increase restrictions on changes in land cover (see Land Use paper)
- Expand the use of LID site practices in developing areas
- Assist local governments in the integration of LID practices in local ordinances and development codes.
- Provide funding for structural retrofits and stormwater basin plans
- Support additional research and monitoring to update the science needed to implement baseflow and normative flow standards

4b. **Develop rules for water reclamation that promote stormwater reuse for appropriate purposes where it is otherwise treated as wastewater and cannot be used to restore hydrologic processes. (Long-term) (see also 1b.)**

F. Additional long-term actions that address the legal and policy framework for water management and climate change

In addition to the strategies prescribed above that are intended to be implemented within the Puget Sound Partnership Action Agenda timeframe, there are additional, longer term strategies that should begin to be addressed at this time. These include:

5a. **Develop a process to recognize federally reserved instream flow water rights that is acceptable to federal, Tribal, state and other water interests. (Long-term)**

5b. **Amend the current water code to streamline the water rights adjudication process. (Long-term).**
Develop a water right adjudication plan and schedule for each basin and allocate the necessary funding. Consider the funding and testing of pilot water courts.

5c. **Model climate impacts uniformly in the ESU. (Long-term)**
Project the effects of a changing climate on streamflow over time by applying the model created by The Climate Impacts Group (CIG) at the University of Washington (Palmer, 2007) to all major watersheds in the Puget Sound region. Maintain a database of the information developed from the model that is available (through web access) to resource agencies and water suppliers. Update the assessments every 5 or 10 years to reflect new data and knowledge.

5d. **Use the assessments of climate change (from 3a.) to estimate regional and local impacts on water supply, water demand, floods, groundwater, and the ability to meet instream flow requirements and fish targets. (Long-term)**

5e. **Develop strategies that address the impacts identified in 3b. (Long-term)**
As part of strategy development, Ecology should continue to coordinate with the U.S. Mayors Climate Protection Agreement to seek ways to mitigate impacts and increase public awareness.

G. Timeline for implementing actions

Sequencing considerations and time to implementation were primary factors in determining the timeline for implementation of the actions described above. Population forecasts indicate that growth presents a greater near-term (2020) threat to water resources and supply, while climate change impacts are perceived as longer term and will be different in different parts of the Puget Sound region.

Some actions are considered beneficial, but they will take a very long time to implement. As such, they are listed as long-term actions and addressed in Section E, above. However, their importance should not be understated. Examples include streamlining the water right adjudication process, developing a process to recognize federally reserved water rights, and integrating climate change prediction in water planning efforts.

Criteria for prioritizing actions to address instream and out-of-stream freshwater supply needs

The following criteria are considered important in determining and prioritizing actions that will address the threats to freshwater supply as discussed above. Priority should be given to solutions that:

- Link ecosystem elements for coordinated management in an effort to enhance ecosystem function
- Provide scientific basis for understanding and solving the problem/issue

- Have a high likelihood of measurable success
- Result in long-term effectiveness
- Are cost effective
- Address threats of greatest urgency
- Use tools that are available now and could be easily implemented (e.g., conservation, efficiency programs, metering, monitoring, and compliance).

How will we know we are making progress? Scientific and Policy Based Outcomes and Associated Benchmarks

A. What specific objectives might be used to demonstrate progress toward the goals for water quantity?

By major strategy area, suggested specific objectives are as follows:

1. Address policy linkages that enable an integrated Ecosystem Approach to Environmental Planning in Puget Sound
    - Identify and develop ecosystem-wide, integrated management programs. This will require strong regional leadership and political will.

2. Promote Demand Management: identify water needs or goals for people by watershed (WRIA) and develop conservation and reuse. .
    - Compile a regional summary (Puget Sound basin wide) of current water use (all sectors), projected water use, and water supply (consider climate change impacts).
    - Establish conservation targets – e.g., Puget Sound per capita water use factor.
    - Establish purveyor conservation targets.
    - Identify a target number of ASR and desalinization projects and equivalent streamflow savings.
    - Determine the percent of water system plans that have adequate water supply to meet the 2020 threshold (projecting adequate supply through 2020).

3. Protect and Enhance Instream Flows through Flow Targets linked to Fish Habitat Needs (includes compliance and enforcement)
    - Codify new or revised instream flow rules for all mainstem rivers and major tributaries in Puget Sound for use in water supply management by a determined target date of 20xx.
    - Assess and prioritize flow impairments in a target number of WRIAs by a determined target date of 2015.
    - Establish and codify salmon recovery flow targets.
    - Identify the number of illegal water users and curtail water use.
    - Verify the percentage of water use currently metered.
    - Improve the ability to manage exempt wells by general permit or other means.

4. More Effectively Manage Stormwater Quantity to Address Alteration of Watershed Processes Caused by Land Development and Clearing.
    - Increase the number of ordinances or local development codes that include LID and structural stormwater retrofit practices.
    - Inclusion of baseflow requirements in the Western Washington Stormwater Manual

B. *What aspects of program implementation and expected ecosystem and programmatic outcomes would be important to evaluate and track progress on this topic?*

1. Status and trend of ecosystem condition.
   - River/stream discharge
   - Groundwater elevation
   - Water temperature
   - Connectivity to floodplain
   - Pool/riffle/run habitat composition and distribution
   - Species (identify species and specific metrics)

2. Status and trend of threats.
   - Water use (per capita use, water system use, WRIA use – including exempt wells, metered water use)
   - Percent of impervious surface by subbasin

3. Project, program, and/or strategy effectiveness (in achieving direct outcomes).
   - Per capita water use reduced/increased
   - Total water use reduced/increased
   - Percent impervious surface reduced/increased
   - Increase/decrease in distribution of flow dependent keystone species, species of concern
   - Increase/decrease in species population statistics

C. *What aspects of progress evaluation are most important to start immediately?*

- Baseline monitoring:
  1. Hydrology (address gaps in stream gage network, groundwater levels, connectivity to surface water/ effects from pumping)
  2. Biology (surveys of fish and other biota)

  (Consider using the Indicators of Hydrologic Alteration (IHA) framework and statistical package for baseline monitoring and evaluating the condition of flow regimes – See question S2)
- Flow/biota relationships
- Survey of people's perceptions of freshwater, water use, etc., and what would change their behaviors
- A refined description of actions and metrics that could be used to evaluate behavior change
- Tracking funding and resource allocation trends for implementing and enforcing freshwater management programs.

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Appendix A

Summary of Freshwater Resource Adequacy

Table P1-1: Water Quantity Policies and Programs

Program/Policy	Threat Addressed	Managing Agency	Goal of Program or Policy	Location Or Scale	Effectiveness In Achieving Intended Water Quantity Goals
Instream flow rule making **RCW 90.22, 90.54**	Low flows	Ecology	Protection of instream values	Developed at the WRIA scale	Regulations provide a baseline for protecting flows; earlier rules did not adequately address groundwater withdrawals
Land Use Planning /Critical Areas Ordinances **RCW 36.70A**	Loss of habitat, geohazards, impacts to aquifer recharge areas	Local governments	Protect critical habitat, avoid geohazards, protection of aquifer recharge zones	Developed at the county scale	Ordinances have been adopted by counties, updates underway
Shoreline program **RCW 90.58**	Impacts to riparian areas	Local governments	The Shoreline Management Act has three broad goals: 1) Encourage water-dependent uses; 2) protect shoreline natural resources; and 3) promote public access	Developed at the county scale	Local governments in the process of revising their Shoreline Master Programs
Salmon recovery planning **RCW 77.85**	Habitat, harvest, hatcheries and hydro impacts to listed salmon	Puget Sound Partnership	Healthy and harvestable populations of salmon	ESU scale	Plan has been developed, recovery will take time
Watershed planning (including storage) **RCW 90.82**	All plans were to address water supply issues, some watershed plans are addressing instream flows	Local Planning Units	Water quantity and optional elements of instream flows, water quality, and habitat	Planning is occurring at the WRIA scale; not all WRIA's have planning groups	Some watersheds have elected not to conduct watershed plans, some of the planning efforts have been terminated, and others have reached the implementation stage
Flood control management program **RCW 86**	High flows	Local governments	Protect communities at risk, restore floodplain function	Planning occurs at the local government scale	Floodplain management is designed to reduce the risks to communities, however some measures have impacted aquatic habitat
HPAs **RCW 77.55**	Protects instream habitat	WA Department of Fish and Wildlife (WDFW)	Prevent habitat impacts from projects in the stream channel	Site specific permits for projects throughout the ESU	See Land Use Topic Forum

Program/Policy	Threat Addressed	Managing Agency	Goal of Program or Policy	Location Or Scale	Effectiveness In Achieving Intended Water Quantity Goals
HCPs **Endangered Species Act (ESA) Section 10**	Habitat for threatened species	NOAA Fisheries reviews and approves plans	A Habitat Conservation Plan (HCP), designed to offset any harmful effects the proposed activity might have on the species. The HCP process allows development to proceed while promoting listed species conservation. The "No Surprises" regulation provides assurances to landowners participating in HCP efforts.	An HCP is tied to a landowner or project.	
FERC – Section 401 Permit, Clean Water Act	Effects of hydroelectric projects on streamflow and water quality	FERC	Section 401 certification is required for any permit or license issued by a federal agency for any activity that may result in a discharge into waters of the state to ensure that the proposed project will not violate state water quality standards. This water quality certification is part of the 1974 Clean Water Act, which allows each state to have input into projects that may affect its waters (rivers, streams, lakes, and wetlands).	Project specific	
Water System Plans **RCW 70.116**	Water availability for human use	WDOH	Under the Coordination Act and WDOH regulations, CWSPs are created for the purpose of ensuring an adequate supply of potable water for domestic, commercial, and industrial use through coordinated water supply planning and development. To further that objective, CWSPs provide for minimum planning and design standards to ensure water systems are consistent with regional needs. CWSPs are also intended to assist state agencies in the orderly provision of financial assistance, and in helping water systems meet reasonable standards of quality, quantity and pressure.	Water System Service Area scale	
Municipal Water Law of 2003 **Engrossed Second Substitute House Bill 1338**[24]	Water availability for human use	WDOH and Ecology	Generally intended to provide more certainty and flexibility for water suppliers while also requiring more conservation.	Water System Service Area scale	Recent legal challenges to definitions of municipal water supply and municipal purposes have limited the effectiveness of the intended policy goals

[24] Amended: RCW 90.03.015, 90.03.260, 3 90.03.386, 90.03.330, 90.48.495, 90.48.112, 90.46.120, and 70.119A.110; Added new sections to chapter 90.03 RCW; 70.119A RCW; 43.20 RCW; 90.82 RCW; and 7 90.54 RCW.

Program/Policy	Threat Addressed	Managing Agency	Goal of Program or Policy	Location Or Scale	Effectiveness In Achieving Intended Water Quantity Goals
Water quality **RCW 90.48**	Point source and non-point pollution	Ecology	Attain and protect water quality standards through development of Total Maximum Daily Load allocation and requirement of National Pollutant Discharge Elimination System (NPDES) permits for point sources.	Specific to a watershed or entity	Total Maximum Daily Load (TMDL) studies alone do not restore water quality; this occurs through the implementation of specific actions. Programs to improve stream reaches specifically designated as "flow impaired" on the 303D list of impaired water bodies have not been developed. NPDES requirements regulate the water quality impacts from discharging pollutants.
Stormwater quantity **RCW 90.48**	Urban runoff from impervious surfaces	Ecology	Prevent stormwater from degrading water in rivers, lakes, streams, and marine waters through NPDES municipal stormwater general permit program.	Local governments develop stormwater programs	Stormwater programs must be accompanied by land use planning, retrofits, basin plans, and expanded LID.
Water Allocation/Water Rights **RCW 90.03, 90.44**	Provides a right to use water for beneficial purposes	Ecology	The purpose is to provide water for beneficial uses. A water right has a purpose of use, a point of diversion or withdrawal, a place of use, a quantity of use, and a priority date. The system is governed by a seniority system – prior appropriation. When water is not available, junior users are subject to interruption of supply in order to protect the rights of senior users.	Water rights are appurtenant to a parcel of land and they have a defined place of use.	Water rights have been issued throughout the ESU for a range of purposes including municipal, industrial, domestic, and agriculture
Water Marketing – Trust water program, etc. **RCW 90.42**	Restoration of low flows or water supply for people	Ecology	Trust water rights protect a water right from relinquishment and can be used to restore streamflows or provide water for out-of-stream uses	Trust water rights occur at a river reach scale	The state has processed a number of trust water rights but the effectiveness of the program (in terms of fish productivity and abundance) has not been fully evaluated
Aquifer Storage and Recovery **WAC 173-157**	Water availability for Human use	Ecology	To artificially store water in underground geological formations and subsequently recover it for beneficial use.	Statewide scale	
Underground Injection Control Program **WAC 173-218**	Groundwater recharge	Ecology	Preserve and protect groundwater by regulating the discharge of fluid in underground injection wells.	Statewide scale	

Program/Policy	Threat Addressed	Managing Agency	Goal of Program or Policy	Location Or Scale	Effectiveness In Achieving Intended Water Quantity Goals
AG Efficiencies Program	Inefficient use of irrigation water	Ecology	Provide grants to irrigators for efficiency improvements	Occurs at the irrigation district scale	Notable flow improvements have occurred, e.g. in the Dungeness Watershed
Comprehensive Irrigation District Management Plan	Adequacy of water supply for agriculture	Western Washington Agricultural Association	Provide for agricultural landowners/irrigators to develop area-wide plans for water resource management. It is a voluntary program that is engaging these landowners in collaborative solutions for irrigation water use and instream/resource improvements.	Dungeness/ Quilcene Basins. Preliminary work in the Skagit and Nooksack (Bertrand Ck) Basins	In progress
Enforcement Programs for Water Rights **RCW 90.03**	Unauthorized or excessive water use that can impair streamflow or senior water rights	Ecology	The goal of the compliance program is to manage the water resources of the public by ensuring voluntary compliance with state water law, and by taking consistent, fair, and assertive enforcement actions throughout the state. Ecology relies on technical assistance, voluntary compliance, and formal enforcement to gain compliance with water laws. Efforts are being concentrated in 16 fish-critical basins across the state where low streamflows are a limiting factor for salmon populations.	Compliance occurs at the water right scale	Lack of enforcement resources in the Ecology regional offices is limiting the program's effectiveness
Climate Change "Program"/policy	Reduced water supply for instream resources and human use	Ecology	To prevent and adapt to changing climate conditions	Statewide scale	Too early to evaluate the effectiveness, recommendations only recently adopted
SWSLs **RCW 90.22**	Low flow	WDFW / Ecology	Ecology has the authority to close surface waters by rule to further consumptive appropriation based upon recommendations from WDFW	Specific streams within a WRIA	Has been effective in halting the issuance of new water rights in basins that are still needing an instream flow rule
Sea Water Intrusion Programs	Loss of coastal groundwater supply due to seawater intrusion	County	Management and monitoring of coastal water supply aquifers to avoid and mitigate sea water impacts.	Island, Jefferson, San Juan	Variable, Island County most effective at monitoring and preventing seawater intrusion, Counties generally plagued by confusion over who has jurisdiction: Ecology or County

Program/Policy	Threat Addressed	Managing Agency	Goal of Program or Policy	Location Or Scale	Effectiveness In Achieving Intended Water Quantity Goals
Desalination	Lack of available freshwater source.	Ecology (for brine discharge permit), WDOH	Produce sole or supplemental water source for potable purposes. Currently being explored as a supplemental source option in WRIA 17. Operation of desalination plant should take pressure off of surface and groundwater resources, keeping more water in the aquifer to be discharged during low flow periods.	Coastal areas with sufficient current and environmental conditions.	Have typically been used by island communities on the San Juans to meet potable water demands either as sole source or supplemental source.
Water Resources & Development Act [WRDA92]	Loss of natural flow regime due to dam operation	US Army Corp of Engineers	Requirement to identify impacts and benefits of dam projects to the public. Has resulted in coordination with state, tribes, local flood management agencies, and federal fisheries agencies.	White River/Puyallup River Basin, Green River, and Lk Wa Ship Canal	Effective in better mimicking natural flows on Green River by use of a flow mgmt team and coordination with tribes, fisheries agencies, and King County's flood management agency.

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Science Question 2 (S2):

Effectiveness and Certainty of Management Approaches to Address Threats to Freshwater Resources

Key Findings from Previous Efforts

A. *What are the main scientific findings relating to management approaches and their documented effectiveness[5]?*

As described in the response to question S1, primary threats to water quantity in the Puget Sound region include: consumptive use of surface and groundwater; increases in consumptive use due to growth; land use practices that increase impervious surfaces, change runoff patterns, disconnect surface and groundwater, and reduce wetland storage; loss of coastal freshwater supply due to seawater intrusion; and modified stream channels (including dams and levees) and floodplains. Climate change will likely compound these effects.

The Land Use/ Habitat and Water Quality Topic Forums are addressing the effectiveness of management approaches aimed at reducing threats associated with land use practices, including increased impervious surfaces, reduced groundwater recharge, and loss of wetlands. This paper focuses on the effectiveness of approaches addressing overcommitment of the resource, stormwater runoff, projected increases in demand, future instream and out-of-stream needs, and the potential effects of climate change.

Management approaches for achieving ecologically sustainable water management can be divided into four categories: (1) flow-setting strategies, (2) stormwater quantity management strategies; (3) demand strategies, and (4) supply strategies.

Flow-Setting Strategies

Flow-setting strategies are aimed at identifying instream flow needs, protecting instream values from future allocation, and making informed water management decisions. The central role of naturally varying water flows (ranging from baseflows to high-flow pulses and floods) in maintaining river, floodplain, and estuarine health has been discussed in the response to question S1.

Existing regulatory instream flows codified by state rule in Washington typically address only low flows. However, advancements in river science suggest that allocations of water to sustain native species and functioning ecosystems, commonly called "environmental flows," need to address the five components of flow: extreme low flows, monthly low flows, high-flow pulses, small floods, and large floods.

A number of methods have been developed for setting environmental flows (Tharme, 2003). Recent water policy advancements in South Africa and Australia have sparked the development of innovative approaches to setting environmental flows that address the whole ecosystem and the interrelationships between its component parts. The building block, DRIFT (Downstream Response to Imposed Flow Transformations), and benchmarking approaches that have been developed in South Africa and Australia have been effective in setting flows that address different components of the ecosystem instead of a single species or life history trait (King, et al., 2003, Postel and Richter, 2003, Brizga, et al., 2002).

Key components of these holistic approaches have been applied in the U.S., for example, in determining a flow prescription for the Savannah River. The resulting flow regime for the Savannah River is being implemented by the U.S.

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[5] Documented effectiveness is defined in this paper as a scientific evaluation of the ability of a proposed water management tool to meet its stated objectives. Documenting the effectiveness of a water management tool generally requires long-term monitoring.

Army Corps of Engineers (Richter, et al., 2006). The DRIFT and benchmarking approaches could be used in the Puget Sound region to determine streamflow regimes that consider “environmental flows.”

Legal and regulatory approaches are necessary to implement these environmental flow regimes once they are quantified. Some of these new methodologies are considered a top-down approach because they begin with a natural flow regime and delineate alteration from that. Upside-down water rights, a system of identifying blocks of water that can be removed from a river system, could be used to legally implement a top-down approach. In this case, the water allocated for out-of-stream use is delineated and the rest of the water with its natural variation remains instream (Silk et al., 2000). Given Washington’s prior appropriation doctrine (“first in time is first in right”), setting instream flows as a state water right with a priority serves to protect the values provided by the instream flow from **future** allocation, but does not restore flow under state law. In the context of prior appropriation, upside-down water rights (Silk, et al. 2000) could currently be implemented in Washington to protect natural hydrological variability and its functions; other approaches would likely require legislative changes in Washington’s water law.

Instream Flow Rule Setting in Washington

Washington is one of the few states in the country with the legal ability to secure water rights for aquatic habitat function and in quantities large enough to prevent further degradation of existing aquatic habitat. Instream flows set by rule in Washington do not affect existing water rights, so they cannot restore flow to the stream. But a new instream flow rule for a river basin can prevent new diversions that could further reduce flows and impact instream habitat. More recent instream flow rules typically address low flows (rather than the full range of flows) with associated management tools that limit future water withdrawals through basin closures or other means. Newer rules also include provisions that track new exempt wells and provide tools for managing and tracking water allocation and use. The effectiveness of these approaches in terms of broader ecosystem health will be evaluated with time.

Stormwater Quantity Management Strategies

Stormwater quantity management strategies focus on minimizing the impacts from changes in timing and volume of run-off from the increase in impervious surfaces or changes in vegetative cover that occur when forests are converted to non-forest cover. There are strategies that address threats to water quantity from new development (e.g., low impact development techniques) and strategies that address threats to water quantity from existing development (e.g., stormwater utility retrofit). However, few of these strategies have been monitored for effectiveness. Those strategies with no known effectiveness monitoring are addressed in question P1. Strategies that have been shown to be effective are discussed below.

There has been some limited monitoring at a parcel and subdivision scale of the effectiveness of various Low Impact Development (LID) Techniques to provide hydrologic controls to more closely mimic pre-development hydrologic functions. Current research indicates that LID techniques such as bioretention, pervious pavement, and rooftop rainwater harvest can significantly reduce the volume of and release rate of stormwater. Examples include:

- The ability of bioretention to effectively capture and infiltrate many small storms entirely, reduce overall volume, reduce peak flows, and slow runoff that is produced (Rushton, 2002; Hunt et al., 2006, Davis et al., 2006; Horner et al., 2007; Horner et al., 2004).

- The use of various types of porous (pervious) pavements locally in Puget Sound has demonstrated effective infiltration of most storms: Initial infiltration rates of pervious pavement are extremely high (several hundred to over 1,000 inches per hour) and local research shows that virtually all storms can be infiltrated (Brattebo and Booth, 2003). Infiltration rates of pervious pavement infiltration will diminish with age, to approximately 10-25% of the original rate, assuming no maintenance (Borgwardt, 2006); however, numerous techniques exist to restore the infiltrative capacity of pervious pavement (Balades et al., 1995). Their effectiveness may be limited only by the ability of the underlying, compacted soils to infiltrate (Brattebo and Booth, 2003).

- Capturing and reusing rainwater that falls on roofs for irrigation and household uses is an effective way to reduce or eliminate the contribution of rooftop runoff to the stormwater system. Rooftop rainwater harvest can be used to more closely replicate pre-development hydrologic conditions (LID Technical Guidance Manual for Puget Sound, 2005). The City of Seattle documented the effectiveness of retrofitting two types of rain gardens in a multiple block drainage area to reduce the quantity and flow rate of stormwater runoff (Horner, et al., 2002). The cost-effectiveness of this type of block drainage retrofit will need to be considered.

- Vegetated or "green" roofs can also reduce runoff and stormwater volume as has been demonstrated over a 4-year period in Portland where peak runoff was reduced in two gardens by 97% and 95%, respectively (City of Portland, 2006). The now-well established roofs also reduced annual stormwater volumes by 63% and 55% in 2005, respectively. This is consistent with monitoring of green roofs by Michigan State University (60% retention, Van Woert et al., 2005) and a literature search conducted by Ryerson University for the City of Toronto (Banting et al., 2005).

By significantly reducing stormwater volume, LID techniques also address water quality concerns. Use of LID techniques throughout the world is further discussed in the S2 Water Quality Paper.

All LID examples above have been implemented at a parcel or subdivision scale. There has not been any basin-wide effort to explore the extent to which retrofitting through LID techniques can rehabilitate full basin hydrology. Computer models indicate that extensive use of LID techniques may result in significant improvements in reducing the extreme levels of daily flow variations, and improve recessional, baseflow, and low flow characteristics (Puget Sound Action Team. 2004).

Demand Strategies

Demand strategies focus on reducing or maintaining consumptive uses of water. Reducing the amount of consumptive use in a watershed, or holding it constant as population increases, is an effective way to help reduce threats of population growth on freshwater resources. This can be done through regulatory, incentive, or education programs that promote water conservation, reclamation, and reuse. Improved efficiencies can be gained through water use compliance programs, water efficiency programs, water rate or pricing structures, infrastructure improvements, low impact development, and changed behaviors. The Water Quality Topic Forum is also addressing reuse alternatives and documented effectiveness of this demand strategy.

Strategies have been applied elsewhere that successfully combine water allocation strategies (similar to Washington's basin closures but on a region-wide scale) with additional return flow and water efficiency requirements. For example, the Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement (2005) not only protected the existing inflows to the Great Lakes, but is intended to also enable restoration of natural flow regimes. The Great Lakes Charter Annex agreements are intended to implement the 2001 Great Lakes Charter Annex, in which Ontario, Quebec, and the eight Great Lakes U.S. states committed to protect and manage the waters of the Great Lakes-St. Lawrence River Basin through agreements that set a common standard for decisions about proposed water uses. These agreements are currently being implemented.

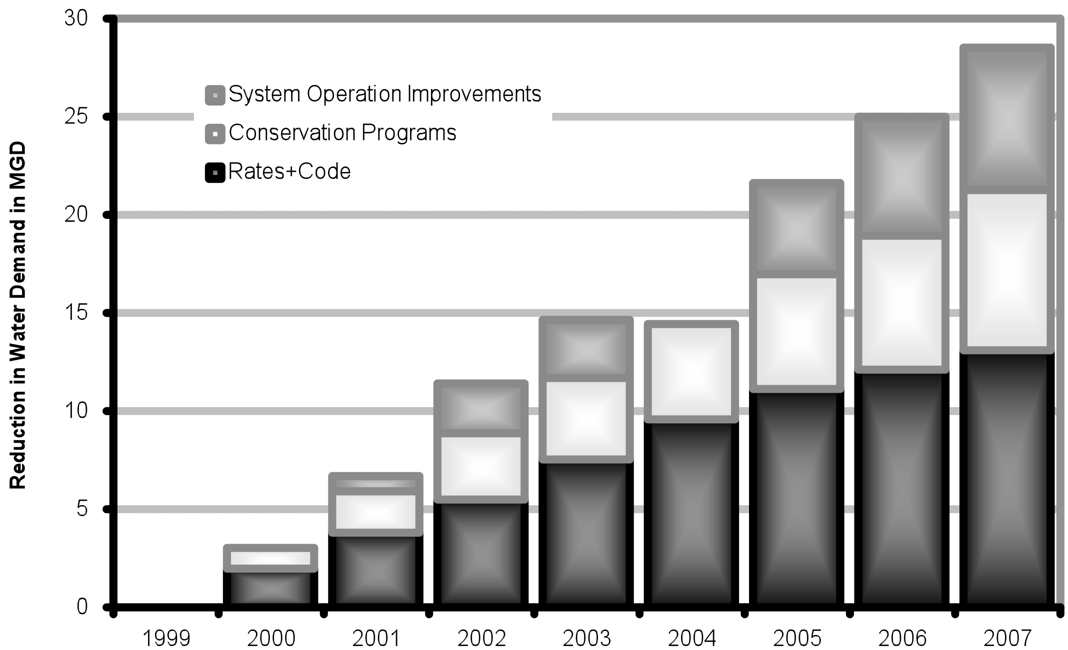
Another strategy that has been shown to conserve water supplies (or limit consumption) is the implementation of an integrated water conservation, reuse, augmentation, and recharge project by the Upper San Pedro Partnership. The project includes wastewater recharge, conservation projects, land use restrictions, landscaping regulations, and rate incentives (or penalties). It is part of a large-scale restoration effort by the City of Sierra Vista and the Upper San Pedro Partnership to return 3.0 to 3.7 million cubic meters of water into the San Pedro River annually and attain an overall goal of a sustainable yield of groundwater by 2011 (Silk and Ciruna, 2004). During its first five years, the Upper San Pedro Partnership focused on assembling the building blocks of a science-based adaptive management program: establishing a regional hydrologic monitoring network and conducting background research to prioritize various water conservation, reuse, augmentation, and recharge strategies. The Upper San Pedro Partnership is now implementing conservation projects and recharge, and using monitoring data to assess project effectiveness in an adaptive management context. Deficit-reducing yields as measured in 2005 exceeded goals for that year (U.S. Department of Interior and USGS, 2007).

Seattle Public Utilities (SPU) administers a regional conservation program that has been effective in reducing per capita water use by 1 percent per person per year. SPU has reported that its "1 percent per person per year by 2010" conservation goal has resulted in an average summer use per typical three-person family of 240 gallons of water per day (80 gallons per capita per day (gpcd)) (SPU, 2005). Seattle's summer usage of 80 gpcd is significantly less than the statewide annual average usage of 97 gpcd reported by Lane (2004). Both total water use and per capita water consumption for the Seattle regional water system continue to decline, despite increases in population served. Total water consumption has declined by 44 mgd or 26% since 1990, while population has increased 16% during those same years. On a per person basis, water consumption has shrunk by one third from 150 to less than 100 gallons per day (Saving Water Partnership, 2008).

Conservation Pricing - Water Rates

One of the most effective tools for water conservation is the utility rate structure. Utility rate structures that promote conservation include the inverted block rate, summer or seasonal rates, and drought provisions. For example, the City of Seattle has a water conservation rate structure that prices water based on the time of year and consumption level tiers. In addition to the water rates, the volume of water used in the winter is used to determine sewer charges, and customers are charged for sewer based on the volume of actual water used. Since sewer costs per unit are larger than water costs per unit, customers get a much stronger conservation price signal than if sewer was charged on a flat rate basis (Seattle Public Utilities, 2008).

The graph below shows the relative impact of pricing and codes (water efficiency codes and standards) on total water savings in Seattle's retail and wholesale service area (Saving Water Partnership, 2008).



Supply Strategies

Supply strategies focus on physically putting water back into the stream to meet instream needs, and identifying alternative sources for out-of-stream beneficial use that have less impact to instream resources. Water supply strategies have been used to restore hydrologic function while providing water supplies for human uses.

There are a limited number of ways to physically put water back into streams. These flow restoration strategies can involve dam operation, off-channel storage, groundwater storage (including aquifer storage and recovery), source exchange, wastewater reclamation and reuse, and water marketing (including leases, water trusts, water purchase).

There are many examples of flow restoration strategies that have been implemented, but monitoring of results and effectiveness does not always occur. A recent compilation of over 37,000 flow and habitat restoration efforts across the U.S. (Bernhardt, et al., 2005) found that many projects had no listed goals, and only 10 percent of the projects reported any type of assessment or follow-up monitoring. It is relatively simple to document that flows have changed, but it is more difficult to demonstrate that the improved flows have achieved the desired ecological outcome. Examples of supply strategies with documented effectiveness monitoring are provided below. Other potential strategies where no documented effectiveness monitoring was available are explored in the response to question P1.

Dam Operation

An entire range of discharges, from low flows to flood flows, is needed to maintain ecological function in streams and rivers. Dams alter the natural flow regime that sustains dynamic aquatic habitats and ecological diversity (Berkamp et al., 2000). However, in cases where flow is highly regulated, understanding of effective ecological discharges can provide a basis for target discharge regimes (Doyle, et al., 2005). In controlled systems, hydropower operations can provide an option to enhance low flows, address stranding of fish and drying of redds, and provide channel flushing flows. Strategies include changing the flow regime from dam releases to more closely mimic the natural flow regime; removing dams; changing diversion structures; or improving fish passage. Bednarek and Hart (2005) documented physical and biological improvements resulting from dam mitigation in the Tennessee River watershed. Other examples in Washington include:

<u>*Hydropower FERC Relicensing Opportunities*</u>

FERC relicensing opportunities depend on a number of factors: project configuration (e.g., mainstem dam vs. off-channel diversion), capacity, project purpose (e.g., power-peaking versus base load), ownership, suite of affected resources, and the willingness of state and federal agencies to advocate for meaningful flow improvements. Some restoration of flows for fish and aquatic habitat in Washington has occurred or will potentially occur through relicensing of hydroelectric projects and negotiations associated with 401 Water Quality Certification under the Clean Water Act. Examples include the North Fork Skokomish River, the Chelan River, the Lewis River (Swift hydro project), the Skagit River, the Condit hydropower dam on the White Salmon, and the LaGrande hydropower project on the Nisqually River. Two of the flow improvements listed will occur in 2009 (Chelan and Lewis) and one is too recent (North Fork Skokomish, new flows started in March 2008) to observe their effectiveness in restoring fish runs. However, increased flows and reduced flow fluctuations associated with Seattle City Light operations on three dams in the Skagit (relicensing between 1980s and 1996) have achieved measurable increases in chum and Chinook salmon runs (Connor and Pflug, 2004; Rob Masonis, Congressional Testimony, 2003; Seattle City Light, 2003). Changes in flow on the White River due to operations at Mud Mountain Dam by the U.S. Army Corps of Engineers and reduced withdrawals from the river by Puget Sound Energy were a primary factor in significant increases in spring Chinook (U.S. Army Corps of Engineers, 2008).

<u>*Tribal Negotiations*</u>

Tribes have negotiated changes in flow regimes from dams used by cities and utilities for water supply, flood control, navigation, and other uses. One example is the Cedar River, where an agreement between the Muckleshoot Tribe and the City of Seattle provided for increased flows during summer and fall for sockeye and Chinook and fish passage into the upper watershed while still providing for multiple uses.

The Puyallup Tribe reached agreement with Puget Sound Energy to secure increased flows and passage for salmon in the Puyallup River through the Electron Hydro project. The Muckleshoot Tribe secured higher instream flows and less flow fluctuation in the Green River for salmon and steelhead in the spring, summer, and fall through negotiation with the City of Tacoma. The Jamestown S'Klallam and Elwha Tribes negotiated with the Dungeness Irrigation District to significantly increase instream flows in the Dungeness River during low flows in the summer/fall for listed salmon species. Most of these operational changes involve monitoring of fish survival from spawning to emergence and adult returns.

<u>*Adaptive Management*</u>

Operational permits and agreements, such as Habitat Conservation Plans (HCPs) and FERC licenses, are now integrating adaptive management components into their operations. Seattle Public Utilities' Cedar River HCP includes consideration of low- and high-flow releases and the function of high flows on an adaptive management basis (City of Seattle, 2008). Adaptive management committees comprised of agency, tribal and utility biologists assist dam operators in determining appropriate releases. Such committees are now part of the Cedar River and Green River dam operations, and the hydroelectric operations on the Cowlitz, Lewis, Chelan, and other rivers.

Other Supply Strategies
A number of other supply side management strategies show promise in addressing impaired streamflows. However, there has been little documentation of the effectiveness of these strategies in improving both hydrologic and ecosystem function. These strategies, listed below, are addressed in the response to question P1:

- Water Marketing/Allocation
- Streamflow Augmentation (including use of reclaimed water)
- Aquifer Storage and Recovery (including use of reclaimed water)
- Desalinization
- Wetland enhancement and restoration

B. How is effectiveness measured and documented?

While a number of agencies monitor streamflow, groundwater, species abundance, or health in Puget Sound, there are no known monitoring programs that include a comprehensive integration of all these elements. Due to climate variability, the lack of knowledge about flow-biota relationships, changing human demands for water, and limited historical monitoring, there is a high degree of uncertainty about the effectiveness of water management approaches and flow protection, and about whether restoration actions meet their intended outcomes.

Performance-based evaluations that assess actual changes in the ecosystem rather than just progress in performing program activities are often lacking in flow restoration and protection activities. For example, the effectiveness monitoring of a streamflow augmentation program needs to not only include measurements of increases in flow, but also longer term measurements of ecosystem improvements due to the flow increases. In other cases, restoration programs have not been implemented long enough to assess results at an ecosystem scale.

Washington's Forum on Monitoring has recently begun a statistically designed, multi-agency evaluation of the effectiveness of habitat restoration activities conducted under Salmon Recovery Planning through a program of intensely monitored watersheds (IMWs) (Currens, et al., 2006). Flow is one of the variables being monitored. Three of the IMWs being established in Washington are located in Puget Sound: in the Strait of Juan de Fuca, Hood Canal, and the Skagit basin. The results of this work are expected to be transferable to other comparable watersheds, but will not likely be comparable to urban watersheds.

C. How should effectiveness be measured and documented?

Evaluating the effectiveness of management techniques requires clear goals and specific indicators. Specific hydrologic parameters can be selected for analysis in response to particular flow-biota relationships or known hydrologic changes (Konrad and Booth, 2002). The "Indicators of Hydrologic Alteration" (IHA) provides a comprehensive view of streamflows and can be used for comparison between pre- and post- impact flow records or trend analysis (e.g., land use changes) (Richter et al., 1996, Richter et al., 1997, Mathews and Richter, 2007). An IHA construct would be helpful in shaping the ecosystem monitoring program for the Puget Sound Partnership if appropriate indicators are selected for tracking.

Changes in management approaches are typically necessary to meet intended goals. The science community has long advocated adaptive approaches in water management (Stanford et al., 1996; Poff et al., 1997, 2003; Richter et al., 1997, 2003). Adaptive management begins with defining mutually acceptable goals related to ecosystem health, economic benefits, and other societal needs and preferences (Rogers and Bestbier, 1997).

D. From a scientific standpoint, which approaches are known to have the most effective results for managing water resources for habitat? For municipal, domestic, agricultural, and industrial uses?

In summary, management approaches that have some level of documented effectiveness in protecting and/or restoring freshwater supply for both instream and out-of-stream purposes include:

- Coordinated demand management,
- Dam operation strategies that provide more optimal flow conditions in river systems with existing controls (dams),
- Instream flow rules that include provisions for future water reservations and basin closures,
- Adequate effectiveness monitoring and adaptive management, and
- Purchase of water rights for instream flow benefit.

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Policy Question 1 (P1):

What Are We Doing (or Not Doing) Now to Address Freshwater Resources in the Puget Sound Region?

Policy approaches being used to manage freshwater resources (surface and groundwater) in the Puget Sound region, for habitat, species, and human uses

A. Threats being addressed by existing policy

Puget Sound's growing human population along with current climate trends will impact the future supply of freshwater in the region. Low streamflows and peak stormwater events already impact many rivers and streams in the region (Currens et al., 2002; Shared Strategy, 2007; NMFS, 2006). As described in the response to question S1, primary threats to water quantity in the Puget Sound region include:

- Consumptive use of surface and groundwater;
- Increases in consumptive use due to human population growth;
- Land use practices that increase impervious surfaces, change run-off patterns, disconnect surface and groundwater, reduce water storage in wetlands, and modify floodplains;
- Loss of coastal water supply due to seawater intrusion; and
- Modified stream channels, including dams and levees.

Climate change will likely compound these effects. Agencies and organizations apply many policy approaches to manage or reduce these threats in Puget Sound, including regulations, plans, programs, incentives, education, and voluntary stewardship. A summary of the most relevant of these programs is presented in Table P1-1, along with the threat it is intended to address. A short summary of these programs is also presented below.

The goals of the Puget Sound Partnership's 2020 Action Agenda are to protect and restore the *Puget Sound ecosystem*.[6] A healthy Puget Sound region can be defined as having quantities of freshwater that are sufficient to:

1. Support freshwater and terrestrial food webs and human uses and enjoyment within all watersheds draining into the Sound,
2. Support estuarine, nearshore, and marine food webs and the habitats upon which they depend; and
3. Protect and restore native species, biodiversity, and the habitats upon which these species depend.

The topic forum teams are addressing a wide range of issues, many of which overlap with water quantity. The Land Use/ Habitat Topic Forum is addressing policy approaches aimed at reducing threats to freshwater quantity associated with land use practices that increase impervious surfaces and decrease forest cover. The Water Quality Topic Forum is addressing policy approaches that address reclaimed water and stormwater runoff quality. This paper focuses on strategies that address overcommitment of the freshwater resource, projected increases in demand, stormwater runoff (quantity), and the implications of these threats for instream and out-of-stream needs now and in the future.

B. Strategies for managing freshwater resources for habitat protection, fish and wildlife, and municipal, industrial, agricultural, and domestic supply

Washington State water law significantly affects how we manage our water. This section first provides a brief description of laws and regulations that control the use of water in Puget Sound, in light of the threats described above. Also

[6] RCW 90.71.300

included is a brief description of various programs and tools that can be used to influence the ways in which we use and manage the freshwater resource.

Washington State Water Law

Management of water supplies in Washington State is based upon the State Water Code.[7] Our water code, and western water law generally, is based on the "prior appropriation doctrine." This doctrine, also known as "first in time, first in right," means that the most senior right in the basin is entitled to its entire quantity of water before the second most senior right receives any water. Those who first put water to beneficial use have seniority in access to water over others when shortages occur. This strict seniority system continues down to the most junior right in the basin and, in times of drought, junior water right holders may not get their allotment of water. [8]

A water right must continue to be used or it will be considered lost through abandonment or relinquishment (commonly referred to as the "use-it-or-lose-it" provision). A water right is subject to relinquishment when all or a portion of the right is not used for five successive years.[9] Water rights perfected for municipal water supply are not subject to relinquishment. In 2003, the Municipal Water Supply-Efficiency Requirements Act (Municipal Water Law) changed the definition of municipal water rights to include most public water systems (this definition is currently being challenged in the courts). Another change resulting from the Municipal Water Law is that surface water rights that have not been used (e.g., unperfected or inchoate rights) may be changed or transferred for municipal supply under certain circumstances. [10]

"Permit-exempt" wells are exempted by statute[11] from having to obtain a water right permit, but they are not exempt from substantive requirements of the Water Code. They are generally limited to 5,000 gallons/day for primarily domestic, lawn and garden irrigation, stock water, and industrial uses. Approximately 3,250 permit-exempt wells have been drilled annually in the Puget Sound area since 1990 (totaling approximately 58,500 wells primarily in rural areas). Such wells are sometimes used in lieu of supplies that require actual water rights in basins that are closed to further appropriation.

Historical overallocation of freshwater, combined with the prior appropriation doctrine, affects our ability to maintain water in streams to protect fish and other instream resources. It also limits mechanisms that might be employed to address threats to the freshwater resource of Puget Sound. In 1969, Ecology was authorized[12] to establish minimum water flows as a water right; however, these instream flow rights are junior rights that are subordinate to existing rights. Therefore, regulatory instream flow setting can protect instream resources from **future** allocation, but because they are junior rights (relatively newer rights), they cannot be depended upon to keep a minimum amount of flow in a stream when a senior user is withdrawing water.

Federal Tribal Reserved Water Rights

Tribal reserved water rights in Washington remain unquantified and likely represent the most senior rights in the state. Federal tribal reserved water rights are primarily based on the Winters doctrine established by the U.S. Supreme Court.[13] These reserved rights are based on an amount of water necessary to fulfill the purpose of the reservation. Tribal reservations include water for long-established uses such as fishing and hunting with a priority date of time immemorial. Courts have generally held that agriculture was also a purpose of tribal reservations created in the 19th century. Federal tribal reserved water rights are not subject to relinquishment or abandonment for non-use (Ecology, 2007b).

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[7] 1917 Surface Water Code and 1945 Groundwater Code (Title 90 with emphasis on chapters 90.03 and 90.44 and 90.14.031(2) RCW).

[8] Prior to the enactment of the 1917 and 1945 water codes, water rights could be acquired by putting water to beneficial use or posting a notice near the point of diversion. These pre-code water rights could be preserved by filing a water right claim under the Claims Registration Act (RCW 90.14.068).

[9] RCW 90.14. 140-180.

[10] RCW 90.03.570.

[11] RCW 90.44.050.

[12] Chapter 90.22.010 RCW.

[13] *Winters v. United States*, 207 U.S. 564 (1908).

Plans and Programs Applicable to Puget Sound Watersheds

Many plans and programs in the state have some relation to management of either instream needs or out-of-stream water use. The programs tend to have a narrow mandate or focus and, individually, may be successful in achieving their programmatic goals. While many tools can be used to protect and restore streamflows, a coordinated strategy or program at a regional level is currently lacking (see further discussion in the response to question P2). Tools include both regulatory-based and incentive-based approaches. The authors are unaware of any conclusive study that compares the relative effectiveness of incentive versus regulatory based management approaches to water quantity issues faced by Puget Sound.

It is not within the scope of this paper to evaluate each existing program separately. As noted above, some programs are also relevant to the Land Use and Water Quality Topic Forums. An abbreviated summary of existing regulations and programs that address threats to freshwater quantity in the Puget Sound region is presented below and in Table P-1.

Instream Flow Setting by Rulemaking: Current instream flow rulemaking activities in the Puget Sound region are summarized by WRIA in Table S1-1. Instream flow rule setting has been effective in protecting rivers from future water withdrawals and to guide Ecology in making informed decisions regarding future water allocation. However, the rules do not put water back into streams that are already being impacted by altered flow regimes. Instream flow water rights are set at the time of the rule; therefore, they are junior to existing senior users. While the setting of instream flows establishes a surface water right for instream values, it alone is seldom adequate in achieving goals for salmon recovery or ecosystem function (American Rivers and WEC, 2003).

Ecology is working to establish instream flow rules in Puget Sound watershed that currently lack such rules. Rules promulgated after 2000 are more comprehensive and often include groundwater closures, water reserves for future consumptive use tracked through county building permits, determinations of seasonal and year-round closures, and other innovative management tools (Ecology, 2008).

Regulatory Stormwater Programs: Federally-required stormwater protections cover urbanized areas within Puget Sound. Ecology administers the federal Clean Water Act's National Pollutant Discharge Elimination System (NPDES) program. In 1995 the agency issued Phase I municipal stormwater permits for King, Pierce and Snohomish counties and the cities of Seattle and Tacoma. This was followed in 2007 by the Phase II Western Washington NPDES municipal stormwater general permit (MS4 permit) to cover 73 smaller Puget Sound cities and urbanized portions of 4 counties (Whatcom, Skagit, Thurston, and Kitsap) around the Phase II cities. The permits require cities and counties to adopt stormwater flow controls and other requirements in the Ecology Stormwater Management Manual for Western Washington (or an equivalent manual) by late 2008 for Phase I permittees, and August 2009 for Phase II local governments. The Clean Water Act NPDES regulations and associated permits focus primarily on water quality; however, the municipal stormwater permits also regulate stormwater flows that directly affect instream resources. These regulations could be expanded to be more directly applicable to stormwater quantity management.

The Ecology Stormwater manual, last revised in 2005, includes minimum requirements, a hydrologic model and best management practices to control runoff from new and re-developed sites, reducing the high flows that can scour streams and damage aquatic resources. The flow control requirements in the Ecology stormwater manual, now imposed by the municipal stormwater permits, address only one aspect of the changes in natural hydrology caused by changing land cover and urbanization – the increase in the frequency and duration of high streamflows that cause accelerated stream channel erosion. Other identified hydrology changes (redistribution of water from baseflow to storm flow, increased daily variation in streamflow, and reduction in low flow) are not addressed by the standards in the Ecology stormwater manual.

Salmon Recovery Planning and Implementation: Salmon recovery planning is occurring in the Puget Sound region under both federal and state laws.[14] Through the work of the Shared Strategy, the Puget Sound region has developed, and the National Marine Fisheries Service (NMFS) has approved a salmon recovery program that calls for protection and restoration measures to be implemented for habitat; however, specific measures related to flow are generally absent.

[14] The Endangered Species Act (federal) and 1998 Salmon Recovery Planning under ESHB 2496 (state).

The watershed chapters of the Salmon Recovery Plan do not establish target flows for fish, and target flows for fish have not been identified to date for the Puget Sound Evolutionarily Significant Unit or ESU (Shared Strategy, 2007, Chapter 6). The lack of watershed-specific actions to address flow as a limiting factor, and the need to address this gap, were called out by NMFS in their regional supplement to the Salmon Recovery Plan (NMFS, 2006).

The Salmon Recovery Plan sets out a three-part strategy to establish protective instream flows, advance instream flow science, and implement flow programs over the next 10 years. Currently, Ecology is continuing to pursue instream flow rule setting in several basins in Puget Sound that do not have flow rules. However, we did not find any flow restoration measures currently being implemented that are focused on achieving those flows.

Watershed Planning and Implementation: Watershed planning[15] is voluntarily occurring in some watersheds in Washington State (see Table S1-1). Where watershed planning has occurred, citizens, Tribes, local governments, and state agencies have worked together in WRIAs to develop watershed management plans that address the quantity of surface and groundwater. Local groups undertaking this type of planning have addressed water quantity issues in their plans, and some have also performed supplemental assessments of instream flows, water quality, storage, and fish habitat needs (Ecology, 2007a). The type and level of analysis conducted by each watershed participating in watershed planning is not consistent across the region. Most of these WRIA groups are just beginning to implement the watershed plans they have developed; therefore the effectiveness of the plans is currently unknown and will likely vary over the region.

Watershed plans developed under RCW 90.82 and Salmon Recovery Plans (by watershed) developed under ESHB 2496 are not always coordinated. Review of available literature indicates there are no similar analyses of needs for freshwater being conducted on a more regional basis.

Critical Areas Ordinances: Cities and counties have adopted critical areas ordinances to protect critical habitat, including wetlands, provide protection of aquifer recharge zones, and address geologic hazards. In some areas, these ordinances have been shown to be effective in addressing the impacts of land use on aquifer recharge and in preserving wetland functions. This strategy is discussed further by the Land Use Topic Forum.

Growth Management: Designation of Urban Growth Areas (UGAs) helps to direct and concentrate growth and infrastructure. Growth management and associated land use planning are also intended to address water supply. However, it is not always possible to “build the water” needed for growth due to regulatory and resource constraints. In some areas of Puget Sound, there is currently a general lack of coordination among local planning processes (e.g., water system plans, comprehensive land use plans, and the Growth Management Act) (Nisqually Indian Tribe, 2003). This can result in uncertainty in the ability to serve projected growth with water. Strategies associated with the Growth Management Act are also discussed by the Land Use Topic Forum.

Water System Planning: Individual water purveyors of greater than 1000 connections update their comprehensive water system plans once every six years. Although these plans are not integrated at a more regional level, the water system planning process enables a local understanding of supply, demand, and future water needs at the scale of a water service area. These plans have been shown to be effective in acknowledging threats of increased consumptive use due to population growth, and identifying where water supply is not physically or legally available to meet future projected demand.

Municipal Water Law: The 2003 Municipal Water Supply Efficiency Requirements Act[16], commonly called the Municipal Water Law, is part of a multi-year effort to reform the state's water laws. Generally, it was designed to provide more certainty and flexibility for water suppliers while also requiring more conservation. The portion of the law that addresses water use efficiencies is discussed below. Provisions of the law also validate the inchoate portion of certificated municipal water rights[17]; however, the definition of a “municipal water supplier” in this context is currently subject to legal

[15] The 1998 Watershed Management Act under ESHB 2514; RCW 90.82
[16] Second Engrossed Second Substitute House Bill 1338
[17] RCW 90.03.330(3)

challenge. Under the statute, municipal suppliers can extend their water delivery to areas within their water system plan service area provided that their water rights are in good standing and that such expansion is consistent with land use and watershed plans. Provisions of the law can result in validation of large paper water rights. Portions of this law were recently ruled unconstitutional, and it will take some time to resolve potential appeals.

Water Use Efficiency Rule under Municipal Water Law: Starting in 2008, provisions in the 2003 Municipal Water Law[18] will require municipal water systems to provide water use efficiency plans within a planning document. These water suppliers will be required to submit annual water efficiency performance reports on annual production, distribution system leakage and authorized consumption volumes (WDOH, 2008). Municipal water suppliers must collect data, forecast demand, evaluate leakage and rate structures that encourage water use efficiency, and evaluate or implement water use efficiency measures as part of a water system plan or small water system management program. However, the goals will vary by water system, and the rule does not include specific targets for efficiencies.

Water Conservation Programs: Conservation programs vary widely within the Puget Sound region. Seattle Public Utilities employs an effective multi-sector and multi-faceted conservation program that could be used as a model in other areas. Many water utilities have already launched water efficiency programs that attempt to reduce the amount of water used without reducing user satisfaction. An umbrella organization, the non-profit Partnership for Water Conservation (http://www.bewatersmart.net/) has been established to join environmental interests with business and utilities to promote water conservation in the Puget Sound region. This regional approach provides more uniform messaging while leveraging available resources.

Ambitious customer conservation programs have been shown to be effective in reducing per capita water use and peak summer season water use (see response to question S2). Utilities in the Puget Sound region have promoted conservation using a variety of methods, including price and rate structures, rebates and incentives, education and information, selected regulatory requirements, and public/private partnerships. Effectiveness of the various conservation methods varies, with leak reduction, rate structures, and education generally being the most popular and cost effective methods (American Water Works Association, 2006) While often more costly, providing customer incentives and rebates on water-using equipment can provide more dependable, long lasting, water savings. However, there is little consistency in goals for water use efficiency over the Puget Sound region.

Streamflow Restoration Opportunities for Puget Sound Watersheds

There are a limited number of ways to physically put water back into streams. Restoration of aquatic ecosystems can include a number of supply side strategies that involve:

- Dam operation,
- Off-channel storage,
- Groundwater storage (including aquifer storage and recovery),
- Source exchange (including desalination and water reuse), and
- Water marketing (including leases, water trusts, water purchase).

These strategies typically involve negotiations between numerous parties and are implemented by dam operators, municipalities, water suppliers, or counties in partnership with others. There are few documented studies that address the effectiveness of these supply side strategies in both providing streamflow benefits and restoring aquatic ecosystems. In addition, impacts of these measures on ecological resources and local and regional watershed hydrology have not been thoroughly assessed. When implementing these strategies, effectiveness monitoring should be conducted to evaluate potential benefits and impact, including any impacts associated with transfer of water between basins or subbasins.

Dam Operations: The effectiveness of altering water releases from dams to more closely mimic the natural flow regime, as well as changing diversion structures and fish passage improvements has been discussed in the response to question S2. Instream flow management is an element of FERC relicensing agreements, Habitat Conservation Plans

[18] WAC 246-290 Part 8 and RCW 70.119A.180

(HCPs), and U.S. Army Corps of Engineers water management operations (Table P1-1). Dam operations can be an effective means of improving flows for instream needs in highly regulated systems. Ecology has the opportunity to influence flow regimes through the Section 401 Water Quality Certification permit under the Clean Water Act. Tribal negotiated releases are common and often successful in improving instream conditions for fish (see the response to question S2). The U.S. Army Corps of Engineers works with a number of fisheries interests as part of the flow management team for Howard Hanson Dam on the Green/Duwamish River.

Source Exchange: Although source exchange techniques have not been implemented widely, nor monitored for effectiveness in improving hydrologic or ecologic function, these techniques could potentially help to shift consumptive use impacts away from surface waters during low-flow periods. Options include:

- Direct streamflow augmentation from groundwater,
- Aquifer storage and recovery,
- Use of reclaimed water coupled with aquifer storage and recovery, and
- Desalination.

These measures are typically implemented by municipalities and counties.

Direct augmentation of surface flows using groundwater has been implemented in Washington State on a limited, small scale. The purpose is typically to mitigate the impacts from new water rights, and therefore the augmentation is for permit compliance and mitigation of future impacts rather than habitat restoration (Ecology, 2003). The City of Kent is currently implementing a program to draw from springs and augment flows in Rock Creek. In Great Britain, the concept of directly pumping groundwater into streams and rivers to improve aquatic habitat and downstream public water supply has been practiced since the 1930s. A number of projects are currently ongoing (Voyce, 2005). In Oregon, direct augmentation is occurring on the Klamath National Wildlife Refuge, where 23,000 acre-feet of water is targeted for pumping from deep aquifers to augment water levels in the Refuge wetlands for environmental purposes (Hainline, 2001).

Desalination is currently used for potable water for some small systems in San Juan and Skagit Counties. In the future it may be a viable option for additional supply in coastal Puget Sound where new appropriations may not meet growing demand. However, consideration should be given to potential impacts to saltwater ecosystems and the costs and energy usage associated with desalination.

A number of aquifer storage and recovery (ASR) projects are in different stages of planning and implementation in the Northwest, including:

- Lacey-Olympia, Tumwater, Thurston County Partnership (LOTT) – Inject reclaimed water to increase groundwater supplies in the three cities (PGG, 2007).

- Lakehaven Utility District, King County – Inject surface water from a reservoir system to increase groundwater supply.

- City of Salem - Treated drinking water from the Santiam River is recharged to the subsurface, and stored in a highly permeable, confined basalt aquifer in the South Salem Hills area. The stored water is used to meet peaking demands and for emergency use, thus reducing diversions from the Santiam River at critical times (Banton and Pitre, 2002).

- Nooksack Watershed, Whatcom County – Inject surface water during higher flow periods to increase recharge to surface water during low-flow months.

- City of Walla Walla – Inject surface water from a reservoir to mitigate streamflow effects of pumping from a shallow aquifer.

Water Marketing/Allocation Strategies: Water banking and leasing, such as that implemented by the Deschutes River Conservancy in Oregon, has been successful in providing water for streamflow restoration. However, water marketing strategies are most effective in basins where legal entitlements to water are known, after an adjudication has occurred. Such strategies are not likely to be as effective in Puget Sound at this time, when water rights and claims have not been confirmed through an adjudication process. Increasing the efficiency of irrigation and putting conserved water in trust is a strategy that is currently being implemented in the Dungeness watershed. The Trust Water Right Program[19] can be used to acquire a water right or a portion of a right for instream flow.

Stormwater Quantity Mitigation Opportunities

Stormwater quantity management strategies focus on minimizing the impacts from changes in timing and volume of run-off as impervious surfaces increase and vegetative cover is removed due to changes in land use. There are strategies that address threats to water quantity from new development and strategies that address threats to water quantity from existing development. Few of these strategies have been monitored to document their effectiveness.

Management Approaches Addressing Stormwater Impacts from New Development : As discussed above, the flow control requirements specified by the Ecology stormwater manual, and imposed by the municipal stormwater permits, address only the increase in the frequency and duration of high streamflows that cause accelerated stream channel erosion. Even in that case, the general approach to high flow control suggested in the guidance is intended to protect only most gravel-embedded streams in the Puget Sound basin. Ideally, the approach should be modified based on specific details of a stream system such as slope, streambed geology and morphology. (Ecology, 2005, Appendix 1-A).

There has not been an opportunity to monitor a watershed being developed while applying the most recent flow control standards in the Ecology manual. Therefore, we have not demonstrated that the standard will successfully protect a watershed from accelerated stream channel erosion. Recent studies suggest that it may not (Goff and Gentry, 2006).

To help address changes to watershed hydrology that are not addressed by the stormwater manual, many have suggested the application of Low Impact Development (LID) techniques[20]. LID techniques can be employed as part of new development to help to minimize stormwater quantity impacts to the full hydrograph, including mitigation of reduced groundwater infiltration and baseflows. As LID tools are applied in a development, the site produces less direct surface water runoff and more water is infiltrated to the ground or evapotranspired. It should be noted that the application of LID techniques do have limitations such as topography and other physical constraints, and may not be appropriate everywhere. Additional grants to local governments to provide incentives to update local development regulations and implement LID strategies are needed. It has been suggested that a system of flow credits be developed to acknowledge flow reductions due to LID practices. Monitoring of existing projects will be necessary to develop a program using flow credits.

Relying solely on engineered LID techniques for new development or reconstruction will not likely result in improvements that completely mimic pre-development hydrology. The removal of trees, vegetation, and the grading of the land that occurs with development present changes cannot be completely mitigated by LID techniques that are focused at a parcel or subdivision scale. “Instead, control of watershed land-cover changes, including limits to both imperviousness and clearing, must be incorporated” (May et al., 1997). This implies that land cover restrictions should be applied in concert with LID techniques to mitigate stormwater impacts at a watershed level.

Management Approaches Addressing Stormwater Impacts from Existing Development: In cases where stormwater runoff from existing development is an ongoing problem, structural retrofit of existing stormwater systems is needed to help restore hydrologic processes. Stormwater basin plans have been developed in some areas of Puget Sound; however, funding is often inadequate to implement stormwater basin plans that prescribe structural retrofits needed to restore hydrologic processes. Retrofitting an LID practice on the individual parcel and neighborhood

[19] RCW 90.42.020(3).

[20] LID techniques can be defined as: “a stormwater management and land development strategy applied at the parcel and subdivision scale that emphasizes conservation and use of on-site natural features integrated with engineered small-scale hydrologic controls to more closely mimic pre-development hydrologic functions”. Examples are provided in the S2 papers for Water Quantity and Water Quality.

(subdivision) scale has been accomplished within the Puget Sound Basin. However, there has not been any basin-scale effort to explore the extent to which retrofitting through LID techniques can rehabilitate basin hydrology. Retrofitting of regional flow control facilities is likely necessary in most basins, but is not common, due to the high cost and the difficulty associated with locating candidate facilities in developed areas. An economic incentive program to assist local jurisdictions in their efforts to retrofit existing stormwater systems is needed, if this approach is found to be effective. Stormwater Retrofit is further discussed in the Water Quality Paper.

Although no stormwater management strategy can fully and adequately restore hydrologic processes altered by land clearing and development, a combination of integrated land use and watershed planning, stormwater basin plans, structural retrofits, and low impact development site practices may be effective in reducing the hydrologic alteration in many watersheds.

C. Where are these approaches adequate to address threats to water supply and resources?

Several existing strategies discussed above appear to be effective in meeting their programmatic goals and addressing some threats to freshwater supply:

- More current instream flow setting (rules promulgated after 2000) provides tools to address threats to instream needs resulting from future consumptive use due to growth, and to link land use to water use.
- Demand management opportunities, such as increased conservation and use of reclaimed water, graywater and rainwater have the potential to significantly decrease per capita water consumption. This can help offset increased use due to population growth and exacerbation due to climate trends.
- Streamflow restoration options associated with dam operations address flow impairment and instream needs.
- Other supply side strategies including source exchange, aquifer storage and recovery, and water marketing (including leases, trusts and purchase) may be useful in putting water in streams during times when flow impairment is most limiting.

Some of the newer programs, policies and rules, based on more current science and more integrated understanding, are thought to be more effective in their focus than previous rules. (For example, instream flow rules that integrate water management tools along with flow setting promulgated after 2000.)

D. Where are these approaches inadequate to address threats to water supply and resources?

The approaches discussed above and listed in Table P1-1, individually, may be successful in their narrower mandate or local focus. However, nowhere in the Puget Sound region do we know of a program that adequately addresses threats to the freshwater resource where broader ecosystem protection and/or restoration goals related to flow are being achieved, and where large populations of people also occupy the watershed.

Despite these current policy approaches, all of the threats to freshwater that are outlined above continue to have local impacts in Puget Sound. This is demonstrated by the anticipated shortfalls in future water supply that have been identified in watershed plans and water system plans. In addition, flow has been identified as a current limiting factor for salmon in many of the watersheds in Puget Sound (WCC, 2005; Currens et al., 2002; Shared Strategy, 2007).

As the human population of Puget Sound grows to 5.2 million by 2020, it is likely that threats associated with consumptive use of groundwater and surface water, and land use impacts associated with growth, will intensify. Climate change will likely compound these effects on the availability of freshwater. The following are specific issues that need to be addressed.

Ecosystem Considerations

Despite the large number of programs that involve some aspect of water quantity, the Puget Sound region does not have policies that address threats from an ecosystem perspective. In addition, land use planning is typically not well integrated with water supply planning. There is no one program that explicitly incorporates the linkages among ecosystem elements at any scale in the region to achieve ecosystem goals. There is no system-wide analysis or framework that integrates water management among the ecosystem elements.

For example, when stormwater systems are designed, no consideration is given to how much water is needed in a stream at certain times of year, nor is stormwater (or other forms of wastewater) customarily retained for the purpose of groundwater recharge. Wastewater and water utilities, in many areas of Puget Sound, "plumb" around the natural hydrology of a watershed, in effect bypassing millions of gallons per day around the freshwater-dependent ecosystem. Limiting factors analyses by WRIA have provided a better understanding of the limiting factors for fish productivity, but we do not have integrated solutions to address these factors. Decentralized treatment that results in distributed systems (stormwater, wastewater, reclaimed water) that essentially return water at the point (or near the point) of withdrawal, may be effective in beginning to restore the natural hydrology of watersheds in Puget Sound. Groundwater quality impacts associated with this type of approach must also be understood to characterize overall effectiveness and risk.

Current approaches to water, land use, and stormwater management do not address the ecosystem as a whole. There appears to be either little incentive or lack of a mechanism to integrate programs within existing management structures and the institutional challenges that are inherent in them. Integration of these elements would require a fundamental realignment of policy and regulation at the state level. The basis of western water law and the regulations that are derived from it provide further regulatory and institutional barriers to full integration of ecosystem components at a policy level. Furthermore, case law continues to evolve and influence the interplay between water and land use.

Gaps in Specific Programs

Gaps we have observed in existing programs are summarized as follows:

- **Current conservation programs** appear inadequate to address peak season use or to initiate social change in water use patterns throughout the entire region, although there are some locally successful programs. This is evidenced by per capita water use data for some utilities and the relatively small percentage of reclaimed water use, region-wide. To address the combined threats of population growth and climate change impacts to streamflow during low-flow periods, per capita consumption of water will need to be reduced in the future.

  Barriers to improving water use efficiency include a use-it or lose-it water right system, state tax and other revenue weighted toward increased water sales, and lack of a statewide water efficiency plan and goal. Attempts to remove legal barriers to the more efficient use of rainwater and stormwater have had limited success in the legislature. In addition, agricultural and industrial self-supplied water users, the largest water uses in the State, have no state water efficiency requirements. Governmental incentives to encourage water use efficiency are generally lacking. Many wastewater utilities don't encourage water use efficiency, and do not send price signals to their customers based on the actual amount of wastewater discharged. A regional approach to evaluating the benefits to Puget Sound of volume based wastewater pricing has not been undertaken.

  The relationship between reduction in overall water use and increased availability of freshwater in streams flowing into Puget Sound is poorly recognized by the general public and experts alike, particularly as it relates to timing of water needs of ecosystems, and the value of benefits added during periods of low streamflows. While the prevailing attitude is the more water left in the steams the better, often, it is the timing and frequency of withdrawals, as much as the volume, which determines the overall impacts to the aquatic ecosystem.

- **Reclaimed water programs** have been slow to take hold due to public acceptance and perceptions, as well as regulatory hurdles. These barriers to reclaimed water use are addressed by the Water Quality Topic Forum. Furthermore, the potential competition for market share between purveyors of potable water and purveyors of reclaimed water is also a barrier to development and use of reclaimed water in cases where suppliers of potable and non-potable supply are different entities. Potable water purveyors have invested heavily in capital projects to support existing infrastructure and have concerns about realizing the benefit of those investments.

- **Regulatory stormwater programs** are focused on controlling runoff from new and re-developed sites by reducing the frequency and duration of high flows that can scour streams. However, the standards do not restore the natural watershed hydrology and do not mitigate for reduction in baseflows or aquifer recharge that result from changing landscapes that generate greater runoff during storm events. Furthermore, **stormwater programs** do not adequately address ongoing damage from runoff in areas of existing development, and funding for retrofit is lacking.

- There are few controls on the proliferation of **permit-exempt wells**, and these wells have no water use reporting requirements (Lane, 2004). Current statutory provisions in the groundwater code[21] make it difficult to address the proliferation of exempt wells, which threaten groundwater supplies by enabling withdrawals to occur on an individual basis without comprehensive monitoring or management.

- The full extent and validity of **water right claims, permits, and certificates** is currently unknown. The adjudication process provides the legal certainty to make such determinations, but the process is complex and time-consuming. This precludes us from understanding how much water is currently allocated and used in the region, and creates uncertainty about providing water for future growth.

- Review of a number of freshwater management plans[22] indicates a **lack of coordination or integration among existing plans at a regional (Puget Sound, Action Area, or WRIA) scale**. None of the planning programs to date have provided a consistent summary of current water use, projected future water use, current supply, and potential shortfalls in meeting projected demands or instream flow needs for the Puget Sound region at any scale (across all WRIAs, action areas, or other jurisdictional areas). This can be attributed to both programmatic inadequacies and to disparities in the scale at which different aspects of water quantity are addressed by programs in the Puget Sound region. Instream needs[23] are typically addressed at a subwatershed scale, not a WRIA scale. However, municipal water use is addressed at the even smaller scale of a water service area. Individual water users operate at the smallest scale, their own projects. Individual water use data for water systems in Puget Sound have not been summarized at a more regional level (Lane, 2004), nor have the data been correlated with watershed-scale instream needs or streamflow.

- The design of **current enforcement programs** or the inability to implement the programs due to a lack of resources renders those programs ineffective at bringing about compliance with the water code. Significant illegal withdrawals continue to occur.

- There is no comprehensive assessment of **the adequacy of flows to support estuarine, nearshore, and marine health**, as stated in the second desired water quantity outcome in the Puget Sound Partnership's definition of a healthy Puget Sound region. Currently this outcome is being addressed indirectly through the adequacy of freshwater flows for instream needs.

- Coastal counties with **seawater intrusion programs** that have limited or inadequate long-term water quality and water level monitoring programs may be susceptible to the threat of seawater intrusion.

E. Is there regional variation throughout the action areas?

State policy and programs are consistent across the Puget Sound region. However, implementation of these policies and programs at the local level reflects local interests and priorities, and varies significantly. As discussed in the response to question S1, water supply issues occur on a very local level, both with respect to out-of-stream demand for human use and instream needs for habitat. Regional summaries of water availability do not exist and local summaries are not always comparable.

[21] RCW 90.44.050.
[22] RCW 90.82 watershed plans, individual water system plans, 2496 salmon recovery plans.
[23] As identified in the limiting factors analysis, defined by instream flow rules and addressed in salmon recovery plans, FERC license agreements, and Habitat Conservation Plans (HCPs).

Freshwater resources should be managed at the regional and local scales, through development of regional goals and objectives, with local solutions and accountability. The importance of local solutions in water management is particularly driven by differing uses of water in rural and urban areas, as well as upland and shoreline areas, and the variable environmental stressors (threats) associated with development in each of these areas. Consumptive uses of water differ significantly between rural areas, where water used for domestic purposes is often returned locally through septic discharge, and urban areas, where wastewater (and stormwater) is often discharged to Puget Sound. Agricultural and rural domestic water use patterns differ appreciably from those associated with municipal, commercial and industrial use in urban areas. Permit exempt wells are proliferating in rural areas and at urban/rural divides. Environmental stressors associated with the different types of development in rural and urban areas have very different impacts on water resources. For example, impacts of exempt wells on baseflows in streams and small tributaries in upland, rural areas are likely measurable. In urban areas, impacts of increased impervious surface and stormwater runoff of the natural hydrology is likely a major factor contributing to earlier and sustained low flows (baseflows). Both urban and rural stressors need to be considered when addressing water management in Puget Sound. Regional solutions must be structured such that they enable local implementation that is tailored to water use and specific environmental stressors associated with a specific area (action area, urban or rural character, upland, lowland, etc.).

Table S1-1: Watershed Scale Assessments, Closures and Instream Flows

Puget Sound Partnership Action Area	WRIA	WRIA Name	2514 Watershed Planning	Instream Flow Rule	Basin Closures	TNC Assessment	King County Regional Water Planning	Basin Assessment	Fish Critical Basins	Salmon Recovery Planning	Limiting Factors Analysis		Central Puget Sound Low Flow Study
											High Flow	Low Flow	
San Juan/Whatcom	**1**	Nooksack	Phase 4; water quality, habitat instream flow	1986	Partially Closed. Basin closed except for lower mainstem Nooksack River	Tier 1			**X**	Low summer/fall flows	POOR	POOR	
San Juan/Whatcom	**2**	San Juan	Phase 4; water quality, habitat instream flow	N/A	No rule. Only one stream not dry in summer						N/A	POOR	
Whidbey	**3**	Lower Skagit - Samish	Phase 3; Draft plan completed in12/03, not finalized or voted on. Limited to Samish Subbasin. instream flow							Low flows	POOR	N/A	
Whidbey	**3&4**	Lower Skagit/ Upper Skagit	Phase 3; instream flow	• Original flow rule, 2001 • Revision adopted 5/15/2006	Not closed now, but will be by existing rule. Unique rule with automatic closure of streams after remaining small allocations (reservation) is used	Tier 1				Hydroelectric dam operations, low flows	POOR	N/A	
Whidbey	**5**	Stilla-guamish	No	• Adopted in 2005	Closed.	Tier 2				Increased magnitude of high flows, low flows	POOR	POOR	summer/fall baseflows
Whidbey	**6**	Island	Phase 4; no optional elements	N/A	No Rule. Camano and Whidbey Islands			**X**			N/A	N/A	
Whidbey	**7**	Snohomish	No	• Adopted in 1979	Partially Closed. 5 mainstem rivers and their tributaries open but 7 streams closed.			**X**	**X**	Increased magnitude of high flows due to loss of connectivity with floodplain	FAIR	POOR	summer/fall baseflows in all AND spring flows and fall freshets in Tolt, Sultan and Wallace Rivers, Riley Slough, Haskel Slough, summer flows in Wallace River

Puget Sound Partnership Action Area	WRIA	WRIA Name	2514 Watershed Planning	Instream Flow Rule	Basin Closures	TNC Assessment	King County Regional Water Planning	Basin Assessment	Fish Critical Basins	Salmon Recovery Planning	Limiting Factors Analysis		Central Puget Sound Low Flow Study
											High Flow	Low Flow	
South-Central Puget Sound	**8**	Cedar-Sammamish	No	• Adopted in 1979	Closed		**X**	**X**	**X**	Low baseflows, higher peak flows following storms, increased flashiness	POOR	POOR	summer/fall baseflows in all AND spring flows and fall freshets in Cedar River[1]
South-Central Puget Sound	**9**	Duwamish-Green	No	• Adopted in 1980	Partially Closed. Mainstem Green River open but tributaries closed, Tribal agreement with Tacoma has higher instream flows than in rule		**X**	**X**	**X**	Changes in flow due to diversion of rivers and streams	POOR	POOR	summer/fall baseflows in all AND spring flows, fall freshets in Middle and Lower Green River
South-Central Puget Sound	**10**	Puyallup-White	No	• Adopted in 1980	Partially Closed by rule in 1980 (WAC 173-510). Mainstem Puyallup and Carbon Rivers open but tributaries including White River closed			**X**	**X**	Diversion of flows and hydroelectric dam operations	POOR	GOOD / POOR	summer/ fall baseflows AND spring flows, fall freshets in Puyallup and White Rivers
South Puget Sound	**11**	Nisqually	Phase 4; water quality, habitat instream flow	• Adopted in 1981. PU found existing flows and closures adequate, except for Mashel River -- IFIM conducted in 2004	Partially Closed. Upper and lower Nisqually open but mid-river and tributaries closed	Tier 2				Reliability of tributary flows	GOOD	GOOD	
South Puget Sound	**12**	Chambers-Clover	Plan not Adopted. Phase 3; water quality, habitat	• Adopted in 1979. Most streams and lakes closed	Closed			**X**	**X**		POOR	POOR	summer/fall baseflows AND spring flows in Clover Creek
South Puget Sound	**13**	Deschutes	Plan not Adopted. Phase 3; water quality, habitat, instream flow	• Adopted in 1980	Closures in 1980 (WAC 173-513). Closed except for two tiny			**X**			POOR	N/A	

Puget Sound Partnership Action Area	WRIA	WRIA Name	2514 Watershed Planning	Instream Flow Rule	Basin Closures	TNC Assessment	King County Regional Water Planning	Basin Assessment	Fish Critical Basins	Salmon Recovery Planning	Limiting Factors Analysis		Central Puget Sound Low Flow Study
											High Flow	Low Flow	
					unnamed streams								
South Puget Sound	**14**	Kennedy-Goldsborough	Phase 3; water quality, habitat, instream flow.	• Adopted in 1984	Partially Closed. Over 20 streams closed only 7 streams open						N/A	N/A	
South Puget Sound and Hood Canal and South Central Sound	**15**	Kitsap	Plan not Adopted. Phase 3; water quality, habitat, instream flow	• Adopted in 1981	Partially Closed. Most streams closed only 4 streams open			**X**		Low summer flows, increased peak flows during rainy season	POOR	N/A	
Hood Canal	**16**	Skokomish - Dosewallips	Phase 4; water quality, habitat instream flow	No Rule – High Priority Basin.	No Rule	Tier 1 and Tier 2				High winter flows, low summer flows	GOOD	N/A	
Hood Canal and Strait of Juan De Fuca	**17**	Quilcene-Snow	Plan Adopted without instream flows. Phase 4; water quality, habitat instream flow	New Rule in process. Estimated Dec 2008. Chapter 173–518 WAC					**X**	Surface and groundwater withdrawals mid-April - Sept.	POOR	POOR	
Strait of Juan De Fuca	**18**	Elwha-Dungeness	Phase 4; water quality, habitat instream flow, storage	New Rule in process. Estimated Dec 2008. Chapter 173–518 WAC					**X**		GOOD	POOR	
Strait of Juan De Fuca	**19**	Lyre-Hoko	Watershed Assessment; water quality, habitat, instream flow	N/A	No Rule					Surface and groundwater withdrawals mid-April - Sept.	POOR	N/A	

Table S1-1 References

Notes

1. The data in the Central Puget Sound Low Flow Study was based on the 2001 Limiting Factors Analysis. Since then, an agreement between the Muckleshoot Tribe and the City of Seattle has provided for increased flows during summer and fall for sockeye and Chinook and fish passage into the upper Cedar River watershed while still providing for multiple uses (WRIA 8).

• 2514 Watershed Planning (RCW 90.82)

Planning units must address water quantity issues in their plans and may also include supplemental assessments of instream flows, water quality, storage and fish habitat needs. All plans must describe strategies and recommend actions that will provide reliable water supplies to meet future instream and out-of-stream needs (Ecology, 2008).

• Instream Flow Rules

Instream flow rules were first executed in the 1970s and 1980s; more recent rulemaking began in 2003. Newer rules are much more complex and comprehensive than earlier rules due to the advancement of science and technical tools. The hydrologic connectivity of groundwater to surface water and freshwater inflows to estuaries has been included in recent rules (Ecology, 2008).

• Basin Closures

Full or partial basin closures have resulted based on inadequate flows and/or overappropriation. In these cases, new water rights will only be appropriated if their impacts are fully mitigated (e.g., drop for drop mitigation).

- TNC Freshwater Assessment

The Nature Conservancy conducted an assessment that addresses 1) the current distribution and status of freshwater ecological systems and native freshwater species at risk, 2) the dominant future threats to freshwater biodiversity in the state, and which watersheds are most susceptible to these threats, and 3) which watersheds and strategies represent the best opportunities for effective freshwater biodiversity conservation in Washington (Skidmore, 2006).

- King County Regional Water Supply Planning – Tributary Streamflow Committee conducted **prioritization of flow impaired tributaries in WRIAs 8 and 9** (http://www.govlink.org/regional-water-planning/).
-
- Basin Assessments

Basin assessments were conducted in the 1990s to compile available information relating to water use, water availability, quantity of water already allocated to existing rights and claims, instream flows, and the hydrology of a basin (Ecology).

- Fish Critical Basins

Ecology and Washington Department of Fish and Wildlife (WDFW) categorized several basins as fish critical basins based upon the Conservation Commission's Limiting Factors Analysis (http://www.ecy.wa.gov/programs/wr/instream-flows/wacq.html).

- Salmon Recovery Planning

The recovery plan proposes a three-part strategy to ensure adequate water for listed Chinook salmon, bull trout and summer chum in the rivers and streams of the Puget Sound Chinook Evolutionarily Significant Unit (Shared Strategy, 2007).

- Limiting Factors Analysis

The limiting factors analysis identified habitat factors, including flow, limiting production of salmon in the state (WCC, 2005).

- Central Puget Sound Low Flow Survey

This report identified streams where low flows limited salmon production (Lombard and Somers, 2004).

For example, the adequacy of groundwater to meet human needs can vary at a local level within a watershed, or even within an aquifer. Some wells may provide adequate supply while others within the same subwatershed may provide inadequate or saline water. Similarly, streamflows may be limiting for human water supply or aquatic species in some tributaries and not in others within a single watershed. Our understanding of whether low flows are adequate for individual aquatic species is further limited by incomplete knowledge of the complex relationship between flow and channel structure and function, off-channel wetland storage, and riparian condition. Full ecosystem function needs to be considered to determine whether flow is "adequate" for species' needs.

Another data gap is our understanding of the relative impacts of stressors (e.g., land development and water withdrawals) on watershed hydrology. We know that land development (resulting in impervious surfaces and increased stormwater runoff) and water withdrawals from wells or surface water diversions alter seasonal flow levels. However, our understanding of the relative contribution from each of these individual modifications to the hydrologic regime and the resulting environmental consequences is unknown. In addition, the relative magnitude of the impact from land development versus water withdrawals varies across the Puget Sound region.

B. *Where do we know that freshwater supply is not adequate to protect habitat function?*

Current Adequacy of Freshwater Supply

We do not know where flow regimes are "adequate" to protect habitat function in Puget Sound, but we do know where they are altered from their natural condition (see A., above). Although flows are monitored in many streams, data are lacking to link flows to salmonid production or the health of other aquatic organisms, or to compare current flow regimes to pre-disturbance flows (WCC, 2005).

A limiting factors analysis (WCC, 2005) indicates that 11 out of 19 watersheds in the Puget Sound region are known to have low flows that may be limiting to fish survival. In addition, 12 out of 19 watersheds are known to have "poor" high-flow ranges for fish. The limiting factors ranking of flows is summarized by WRIA in Table S1-1. It should be noted that the limiting factors analysis did not directly correlate low or high flow to fish production as few basins have studies to quantify a direct relationship. This much-cited reference extrapolated high flow conditions for fish based on the type and age of vegetation (tree) classes and impervious coverage. Poor low flow conditions were based on 303(d) listings for low flows, known salmon mortality due to flows, and stream closures due to over appropriation (WCC, 2005). Individual watershed chapters of the Puget Sound Salmon Recovery Plan (Shared Strategy, 2007) provide additional assessment of factors that limit salmon production in the region. Appendix A provides local examples where low flows appear inadequate for fish and wildlife and habitat type based on numerous local data sources.

The 2004 State of Salmon Watersheds Report lists the Nooksack, Snohomish, Lake Washington, Green, White, Puyallup, Dungeness and Elwha as "water-critical basins" that are over-appropriated. The Stillaguamish and lower Skagit watersheds are listed as "low flow," and are noted to be experiencing significant pressure for increased water use and declining flows. However, data are not presented to document the impact of these flows on aquatic species. Of all the Puget Sound Chinook natal watersheds, only the mid-Hood Canal and the upper Skagit were not listed as having potential flow problems for salmon (State of Washington Governor's Salmon Recovery Office, 2004; NMFS, 2006).

Data Gaps and Uncertainties

Major gaps in our understanding of the adequacy of flows for habitat include:

- Low-flow and high-flow requirements for aquatic species are not well understood, and they are intricately linked to other elements of the ecosystem. For example, relationships between flow and the four Viable Salmon Population (VSP) parameters (abundance, productivity, spatial structure, and diversity) that are used to determine the relative health of salmonids have not been determined in the Puget Sound region (Shared Strategy, 2007).

- There is no regional assessment of the adequacy of flow variations for optimum habitat function, although the Seattle Public Utilities Cedar River Habitat Conservation Plan (HCP) includes high- and low-flow release prescriptions that are considered beneficial and newer operational permits for FERC licenses are considering high- and low-flow release prescriptions (e.g., Cushman Hydroelectric Project).

- Local data about the effects of flow alterations on native species are available. For example, local empirical data indicate that there are adverse effects of scouring floods and low spawning flows on smolt production (e.g., Seiler et al., 2005). However, such information has not been quantified or extrapolated more regionally.

- There are no known studies that address the potential adequacy of flows for aquatic habitat in the future. Threats such as increased groundwater and surface water withdrawals due to population growth, associated land use impacts, and climate change may impair flows in watersheds where this is not currently an issue.

C. *Where do we know that freshwater supply is not adequate to meet current and future human demands (e.g., municipal, domestic, agricultural, industrial)?*

Current Demand for Freshwater

Almost every watershed in Puget Sound has local areas where freshwater supplies are not adequate to meet current human demands. Freshwater use for domestic, irrigation, and industrial purposes in the Puget Sound Region in 2000 is estimated to be close to 600 million gallons per day (mgd) (Lane, 2004). The adequacy of water supply is different in every watershed and varies around the Puget Sound region. There is no regional summary of the adequacy of water supply to meet human needs in Puget Sound. Appendix A indicates WRIAs where local issues have occurred, but it is by no means comprehensive.

Domestic, Irrigation, and Industrial Freshwater Use in the Puget Sound Region in million gallons per day, Year 2000[3]

Domestic			Industrial		
Self-supplied	**Public-supplied**	**Irrigation**	**Self-supplied**	**Public-supplied**	**Total**
56.64	319.14	70.16	103.84	43.55	593.33

Exempt Wells

Exempt wells represent an unquantified, growing, and potentially significant component of the regional freshwater supply. The full effects of current domestic use by permit-exempt wells are unknown. The

[3] Freshwater use is reported by County by Lane (2004). The totals reported in this table represent county-wide use for the following counties: Whatcom, Skagit, Snohomish, San Juan, Island, King, Thurston, Pierce, Kitsap, Clallam, Jefferson, and Mason. Only a portion of Thurston, Clallam, Jefferson, and Mason counties are included in the Puget Sound region, therefore, the numbers here slightly overestimate actual use in the Puget Sound region (Figure S1-2).

exempt wells are individually minor in volume, but collectively comprise a component of freshwater use that is unaccounted for, unregulated, and continuing to increase with population growth in the region.

The well exemption hinders the state's ability to manage this portion of Puget Sound's water supply. Over 58,000 well logs from the Puget Sound region have been received by Washington State Department of Ecology (Ecology) since 1990 (over 3,200 wells per year) (Ecology, 2008a). This represents reported drilling of permit-exempt and larger wells that require water rights. It is estimated that approximately 95 percent of these wells are permit-exempt, and that an additional 20 percent of permit-exempt wells go unreported statewide (Ecology, 2008b). By county, self-supplied water use (Group B systems and permit-exempt wells) comprised between 5 and 54 percent of total domestic water use in 2000 for counties located within the Puget Sound basin (Lane, 2004). Typically, more rural counties have a greater percentage of exempt well use.

Future Demand for Freshwater

Puget Sound's growing human population poses significant threats to freshwater supply in the region. The current population of the Puget Sound region of 3.8 million may increase by another 1.4 million people by 2020 (PSP, 2006). With a year 2000 average per capita domestic water use of approximately 97 gallons per day (gpdc) (Lane, 2004), this amounts to a need for an additional 136 million gallons of water each day for domestic and municipal uses on an average annual basis in 2020. Peak flow demands during dry, warm summer months will be greater. Preliminary water withdrawal data (USGS, 2005) indicate that the average per capita water use averaged across all counties comprising the Puget Sound region may have decreased as much as nine percent between 2000 and 2005. Once confirmed, these data could reduce the forecasted water use for 2020.

Many watershed plans[4] and water system plans address uncertainty in meeting future needs either due to water supply shortfalls or seawater intrusion (San Juan County WRMC, 2005; Island County WRMC, 2005; Nisqually Indian Tribe, 2003; WRIA 1 Watershed Planning Unit, 2005; Cascadia Consulting Group, 2007; HDR Engineering, 2007). These evaluations generally indicate that there are a number of water systems that do not have adequate physical water or water rights to accommodate projected future water use.

Water can be physically available, but limited by legal availability. This occurs in areas where regulatory instream flows are not met throughout the year and/or where basins have been closed to new appropriations for municipal, industrial, commercial, and/or agricultural use. Ecology cannot make a finding of water availability if streamflows are not meeting regulated flow levels on a regular basis. Areas where instream flows have been set and basin closures have occurred are indicated in Table S1-1.

Instream flow rules have been set by Ecology in 12 watersheds in the Puget Sound region. In most of these 12 watersheds, streamflows were met less than 50 percent of the time during low-flow periods, and in some watersheds, less than 80 percent of the time. In these cases, Ecology has difficulty in making a finding of water availability and cannot appropriate additional water without full mitigation. In closed basins, junior water rights for uninterruptible supplies cannot be obtained without fully mitigating for the impact to impaired streams. This situation makes obtaining new water rights for future water uses uncertain and more difficult. Watersheds without instream flow rules include the San Juan, Island, Skokomish – Dosewallips, Quilcene-Snow, Elwha-Dungenes, and Lyre-Hoko (WRIAs 2, 6, 16, 17, 18 and 19). Lack of an instream flow rule in a

Can instream flows be achieved?

Instream flows are intended to protect the natural variation in flows during dry times of the year when flows are most limiting for fish. Wet summers produce more fish than dry summers, all else being equal. To benefit from fish production in wet summers, instream flows are set so that they do not preclude the less frequently achieved wet summer flows. Allocating water elsewhere during a wet year would result in dry year flows year after year. Therefore, instream flows are not always met in dry years because they are set higher than the expected flow in a dry summer; that is intentional. Only drought flows are achieved every year.

Hal Beecher, 2008

[4] Where watershed planning is occurring under RCW 90.82.

watershed does not imply that Ecology could make a finding of water availability in the watershed. Ecology is attempting to set flow rules in Puget Sound watersheds that currently lack them in the next several years.

Data Gaps and Uncertainties

Major gaps in our understanding of human water demands include:

- **There is no Puget Sound-wide or statewide program that compiles and reports water use information** (Lane, 2004). Where watershed planning has occurred (under Revised Code of Washington (RCW) 90.82), local communities have attempted to identify local problem areas for water supply and develop demand solutions. However, watershed planning under RCW 90.82 is not occurring in all watersheds in the Puget Sound region, nor are the data consistent between watersheds planning under the act, and so data on potential water supply shortfalls are not available consistently throughout the Sound.

- **Water system plans are numerous and not regionally compiled.** Water supply management is typically addressed at the scale of a retail or wholesale service area of a water system through a water system plan. The plan addresses population projections, demand forecasts, supply sources, and infrastructure requirements. There are over 2,300 Group A water systems (Community and Non-community water systems with 15 or greater connections) identified within the Puget Sound region (Washington State Department of Health (WDOH), 2008). They represent 66% of the total number of Group A water systems in the State (4,193). Water systems with over 1,000 connections, those expanding, and new water systems are required to submit water system plans for review and approval to the WDOH. Water system plans are required to be updated once every six years. However, WDOH does not compile water system information at a regional scale.

- **Agricultural water use is not regionally compiled.** Comprehensive Irrigation District Management Plans address the adequacy of water supply for agriculture and have been prepared for portions of the Dungeness, Skagit and Nooksack River watersheds.

- **Commercial and Industrial water use is not regionally compiled.**

- Water rights provide an accounting of permitted water withdrawals. However, **actual water withdrawals may differ from the water right, and illegal water use occurs**.

- **Regional water supply planning is not occurring everywhere.** In some areas such as central Puget Sound, regional water supply planning is comparing regional water demand with regional water availability (CPSWSF, in process). This has not occurred in other areas in Puget Sound.

- **Permit-exempt water use is not well accounted for.** More current instream flow rules call for tracking future installation and use of permit-exempt wells. Reservations for new domestic and municipal supply have been established in those basins, and new uses are tracked through a reservation as a condition of the instream flow rule. Other watersheds that do not have instream flow rules, or have older flow rules, have no method of accounting for current or future permit-exempt water use.

D. Watershed scale assessments and other data sources

Watershed Scale Assessments

Numerous studies and planning processes have addressed aspects of freshwater supply needs, some focusing on species' needs and others including human water uses. Table S1-1 describes these assessments and indicates where these studies and planning processes have been conducted in the Puget Sound region and general outcomes by WRIA. Each has a different geographic coverage and uses different methods for identifying flow needs and inadequacies. Lack of inclusion of a watershed in a study or a planning process does not necessarily indicate that there are or are not water availability issues in that geographic area.

Water Quantity Data

The collection and analysis of data on freshwater quantity, and the use of this information in planning, occurs on geographic scales ranging from individual point locations to coordinated regional monitoring. Surface water data are monitored through stream gages maintained by federal, provincial, state, and local agencies. These gages provide point data that are often used to infer flow conditions in some portion of the upstream area. Many water utilities that divert water from surface water sources collect streamflow data at the point of diversion. Where data do not exist, it is possible to use models to create streamflow records based on rainfall, stream gage data, and runoff characteristics from a similar watershed.

There is no statewide ambient groundwater monitoring program and generally, there is a lack of ambient groundwater monitoring data for Puget Sound. Where groundwater is monitored within Puget Sound, it is not monitored uniformly. Monitoring is primarily performed by local or state agencies. It typically is driven by site-specific needs and limited in scope to particular management objectives (e.g., nitrates, chlorides for seawater intrusion, or other contaminants of concern).

Climate Change Data

For the Puget Sound region, climate change models indicate that reduced snowpack and earlier runoff will likely affect water resources. In many Puget Sound watersheds that are dominated by snowmelt, warming will result in increased winter flows, earlier and reduced peak flows in the spring, and reduced summer flows with higher instream temperatures (PAWG, 2008). These trends will likely increase the number of days when utilities must rely on water stored behind dams as the natural storage, in the form of snowpack, continues to decrease. In basins that are not dominated by snowmelt, groundwater recharge patterns may shift. This will make it more difficult to maintain streamflows for native aquatic species and their habitat, and to provide water for municipal uses (Ruckelshaus and McClure, 2007).

The University of Washington Climate Impacts Group (CIG) has modeled predicted climate change impacts on regional hydrology, regional demand forecasts, and water supply alternatives in Pierce, King, and Snohomish Counties. The work included modeling of the major water supply drainage basins used for water supply in the study area (the Sultan, Tolt, Cedar, Green, and White Rivers). By 2075, the range in ensemble average discharge for the five basins compared to historic flows is predicted to decrease by 27 to 42 percent during the summer and increase by 41 to 57 percent in the winter (Palmer, 2007).

The shift in the hydrograph due to climate change has many implications for water resource management, streamflow augmentation, and ecosystem function (PAWG, 2008). These include:

- Changes in the seasonality of water supply (e.g., reductions in summer);
- Changes in water demand (e.g., potentially increasing evaporation);
- Changes in drought stress;
- Increasing conflicts between water supply and other uses and users of water;

- Changes in low-flow risks;
- Changes in the need for releases from storage to reproduce existing streamflow regime;
- Impacts to ecosystem function as a result of changes in the timing and volume of freshwater inflows (e.g., increased winter peak flows, reduced summer low flows);
- Changes in water resources management related to water quality (e.g., to provide dilution flow or to control temperature);
- Impacts to fish and aquatic ecosystems related to changes in the seasonality and intensity of flows (e.g., increased winter peak flows, reduced summer low flows); and
- Changes in watershed function due to large-scale changes in vegetation (e.g., fire, insect damage).

E. What are the major threats to freshwater supply and availability?

Major threats to freshwater supply and availability include:

- Over commitment of the resource through water withdrawals and diversions;
- Projected increases in domestic, municipal, commercial, and industrial water demand associated with population growth;
- Land use practices that increase impervious surfaces and decrease native vegetation and result in reduced groundwater recharge, higher peak flows, and earlier and sustained low flows (baseflows).
- Altered hydrology, including loss of wetlands and floodplains;
- Loss of coastal groundwater supplies due to seawater intrusion;
- Modified stream channels, including ditching, bank armoring, dams and levees; and
- Altered weather regimes associated with climate change.

All of these threats will continue to impact streamflows and compromise the ability to support freshwater and terrestrial species, as well as the increasing demand for water for human activities and other out-of-stream beneficial uses. Reduced freshwater inflows also impact estuarine, nearshore, and marine food webs and the habitat upon which they depend (Ruckelshaus and McClure, 2007).

F. What is the certainty of our understanding?

As described in earlier sections of this report, there is little certainty regarding freshwater supply, or its adequacy for instream needs and out-of-stream beneficial uses at a regional level. We are certain that demand for water will increase as growth occurs in the Puget Sound, even if per capita demand is reduced by conservation efforts. In the Puget Sound region, most ecological assessments and studies have been broadly focused on habitat conditions and impacts to salmon species listed under the Endangered Species Act, and have not addressed water quantity and streamflow issues. As a result, the information regarding the extent and nature of streamflow issues is in most cases general in nature (Lombard and Somers, 2004). The salmon limiting factors analysis (WCC, 2005), which provides the most detailed statewide assessment, is a snapshot in time of habitat conditions and is not based on quantitative relationships between flow and aquatic species productivity.

In those places where quantitative models and empirical data confirm conclusions, it is reasonable to hold them with confidence. However, given the disparity of data across the Puget Sound region, whether it is gage measurements of freshwater supplies or studies conducted to establish flow-biota relationships, it may not currently be possible to apply site-specific analysis to other areas in the region.

G. What are the main known gaps in our understanding?

Specific topics were detailed earlier in this report. In summary, the main gaps include:

- Data that indicate groundwater use, levels, trends, and depletion on a regional scale;
- Localized hydraulic continuity between surface water and groundwater;
- Hydrologic impacts of climate change, particularly how climate change may alter rainfall patterns.
- Understanding of the relative impact of land development (resulting in impervious surfaces and stormwater runoff) and water withdrawals from wells or surface water diversions on seasonal flow levels.
- A quantitative correlation between streamflow and fish productivity;
- Full understanding of the ecological impact of flow alteration on riparian vegetation, instream primary production, invertebrates, reptiles and amphibians, and birds.
- A quantitative understanding of geomorphology and fish needs during high flows;
- Identification of flow impairments (both low and high flow problems) within the Puget Sound watershed (similar to the inventory of low flow impairments conducted by the King County Tributary Flow Committee (2006) in WRIAs 8 and 9);
- Regional understanding (survey) of water system plans and watershed plans to inform where current water supply is inadequate to meet projected demand between now and 2020;
- Evaluation of freshwater requirements for estuary health; and
- The quantity of water used to meet consumptive needs.

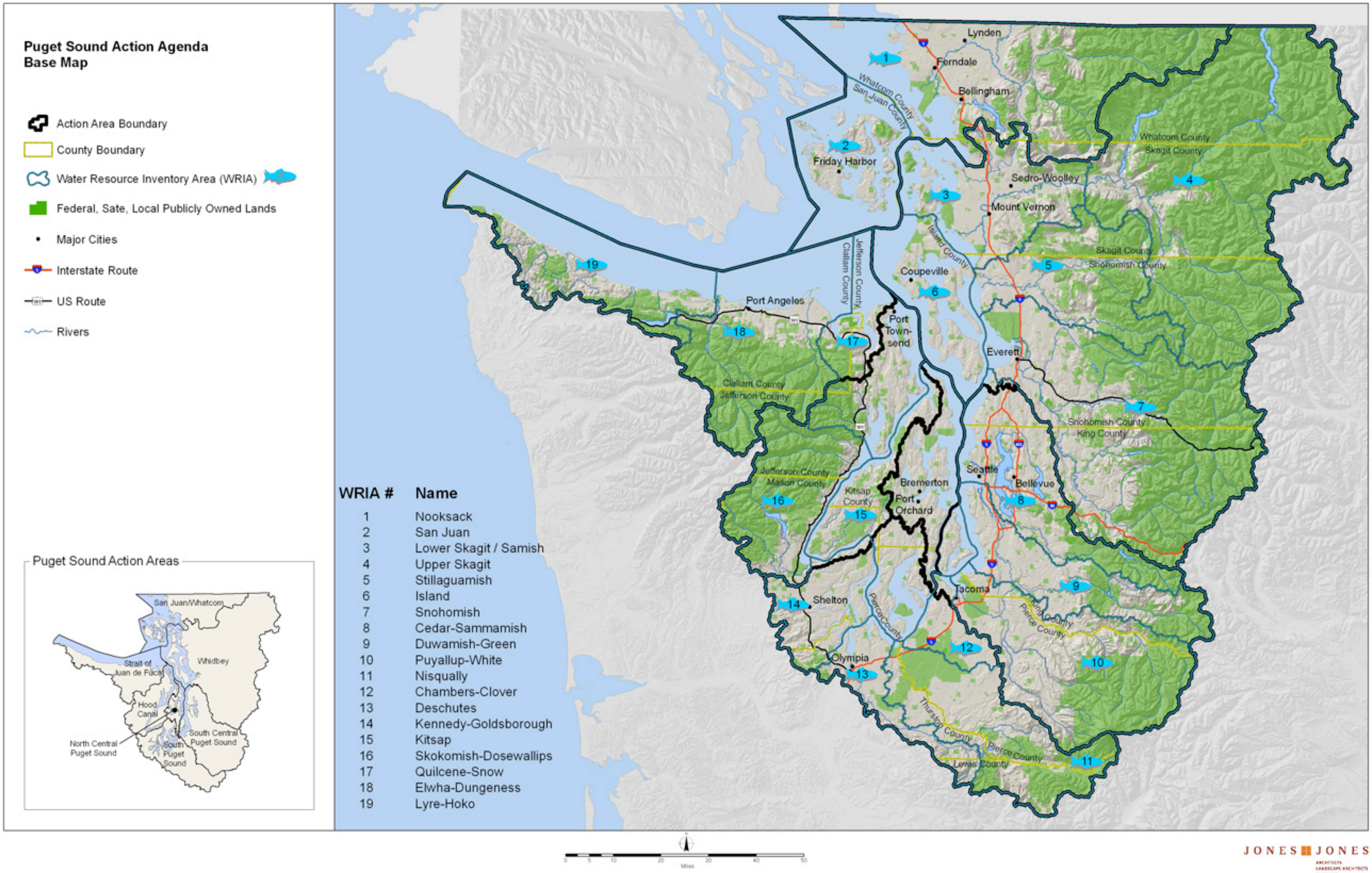

Figure S1-2: Puget Sound Partnership Study Area – Action Areas and WRIAs

- The timing of freshwater inflow has changed between 1948 and 2003. Snowmelt begins 12 days or 2.1 days per decade earlier, and there has been an increase in the occurrence of unusually high and low daily flows (Snover et al., 2005).

- Water budgets developed using the Hydrologic Simulation program FORTRAN (HSPF) or Deep Percolation Model (DPM) and historic data for a small portion of subwatersheds in the Puget Sound indicate an average water budget of: 38.20 inches/year of precipitation, 13.95 inches/year of recharge, 16.76 inches/year of actual evapotranspiration, 7.72 inches/year of surface/subsurface runoff, and 13.68 inches/year of baseflow (Vaccaro et al., 1998).

- Annual freshwater inflows from Puget Sound rivers help drive the marine circulation patterns in Puget Sound. The sub-tidal circulation of Puget Sound is largely driven by the difference in salinity between freshwaters within the Sound and the saltier ocean waters in the Strait of Juan de Fuca. However, circulation in Puget Sound's main basin appears to be more sensitive to variations in ocean salinity compared to freshwater inflows (Ruckelshaus and McClure, 2007)

- While freshwater inflows generally influence surface salinities, different subbasins within the Sound have varying sensitivities to freshwater inflow (Ruckelshaus and McClure, 2007). The transport of deep marine waters into some subbasins is limited by the presence of sills at Admiralty Inlet, Tacoma Narrows and the mouth of Hood Canal. These features partially isolate some subbasins and slow circulation (Ruckelshaus and McClure, 2007).The role of freshwater inflows in some of these areas of the Sound is not well understood.

Changes in Watershed Hydrology

Generally, the healthiest and most biologically productive streams are found in undisturbed watersheds (Booth et al., 2006). However, most watersheds in the Puget Sound region have been altered by urban or suburban land uses, agriculture, or forest practices and many contain facilities that store water or generate power. The hydrology of these watersheds has been altered to varying degrees.

Human uses of land in floodplain areas, dating back to the earliest human settlements and growing in intensity over generations, have resulted in and sustained the need for flood control measures that alter the interaction of naturally variable flows with floodplain habitats. While a natural flow regime (i.e. intensity, timing and frequency of flows) sustains dynamic aquatic habitats and ecological diversity (Berkamp et al., 2000), benefits of flood control measures are derived from reducing potential damage to life, property and infrastructure; crop and livestock losses; service disruptions; and increased poverty (World Bank, 2005; Green et al., 2000; National Research Council (NRC), 1992).

The greatest human population densities in Puget Sound occur in King, Kitsap, Pierce, Snohomish, Island, and Thurston Counties (Washington State Conservation Commission (WCC), 2005). Many studies have documented the effects of increasing human population and associated land use on hydrology. Some of the major effects of increasing human population include:

- Changes in land cover, including forest canopy and riparian vegetation, increase impervious surface, alter flow regimes, decrease aquatic species viability, and displace habitat. As a general rule, the health of stream systems declines with the first incremental loss of forest cover and creation of impervious surface of any extent. When the level of effective impervious surface in the watershed exceeds around 10 percent, or when the forest cover is reduced below 65%, stream channel degradation is obvious and widespread (Booth et al., 2002, Cassin et al., 2005, Morley, 2000). Biological degradation begins and becomes significant at even lower levels of land cover change. May et al. (1997) reported changes in streams with watersheds exceeding 5% total impervious area, including significant reductions in stream biological health and shifts in the ratio of juvenile coho salmon to cutthroat trout. These changes in stream channels and degradation of the biological health in the lower ranges of land cover alteration are primarily associated with changes in the natural hydrology. As land cover alterations increase with greater levels of urbanization, other influences come into play, including reduced water quality and degraded riparian habitat.

- Biological communities in stream systems depend upon the source, timing, and rate of streamflow to help define habitat conditions. Konrad and Booth (2005) describe four hydrologic changes resulting from urban development that are potentially significant to stream ecosystems: “increased frequency of high flows, redistribution of water from baseflow to storm flow, increased daily variation in streamflow, and reduction in low flow.” Generally, increased stormwater runoff quantity results in (a) greater peak flows that damage habitat and subsequently impact aquatic species and impact humans due to flooding, and (b) reduced groundwater infiltration that damages habitat and associated biota through reduced baseflows and impacts humans by reducing water availability during dry periods (Konrad and Booth, 2005). (Stormwater quality impacts are addressed in the Water Quality paper).

  The increase in high flows causes accelerated stream channel erosion displayed by downcutting of the streambed and widening of the channel (Hammer, 1972; Leopold 1973; Heede, 1985, Booth, 1990). These changes are common throughout streams in the urban and urbanizing areas of Puget Sound. Fish need certain combinations of water and sediment fluxes to create favorable channel conditions. “Because land use change in a watershed alters those fluxes, the resulting flow regime and channel configuration no longer tend to favor salmonids” (Booth and Jackson, 1997; Booth and Fuerstenberg, 1994).

- In general, increasing human population density and associated land use changes (urban development) lead to greater differences between low and peak flows (Konrad and Booth, 2005). This may result in channel conditions that are less favorable to native flora and fauna most of the year, and that require higher flows (than typical) to make them favorable during low-flow periods. Given their flashy hydrographs, low habitat heterogeneity and high contaminant loads, urban fish and invertebrate assemblages are limited in species diversity (Bernhardt and Palmer, 2007).

- Increased human population and associated changes in land use also tend to cause increased ditching, draining, diking of floodplains and wetlands, and armoring of streambanks.

- Restoration of urban streams can only occur if hydrologic processes and the spatial distribution of the water-storage capacity are re-established across the urban landscape (Konrad and Booth, 2005, Frissell and Nawa, 1992). The ability to fully restore an urban stream is generally inversely proportional to the extent of urbanization that has already occurred. In streams with watersheds of moderate urbanization (10 to 25%), scientists suggest that restoration of the natural flow regime and re-creation of high quality habitat are endpoints that are highly unlikely without extensive removal of the urban landscape. In those watersheds, various actions to reduce the impacts of urbanization, including reduction in streamflow alterations, may help rehabilitate (not restore) the stream’s condition, and its biologic resources to a moderate level (Center for Watershed Protection, 1998; Booth, 2005). In more highly urbanized watersheds, the ability to rehabilitate the stream to a “good” biological condition is less likely and scientists recommend “modest” rehabilitation goals (Center for Watershed Protection, 1998; Booth, 2005; Booth et al., 2004).

- Full ecosystem function must be considered to determine whether flow is adequate to protect habitat function. “Discharge plays at least four distinct roles in stream ecosystems: material transport, habitat definition, process regulation, and disturbance” (Doyle et al., 2005). Naturally varying high flows as well as minimum low flows are important. Over the evolutionary history of Puget Sound’s native aquatic species, naturally varying flow conditions have played an important role in the adaptation of those species to local river and stream systems and habitats. When flow conditions fall outside of the range of historic natural variation, the viability of native species adapted to that local variation in flow can be affected (Spence et al., 1996; Naiman et al., 1992, 2008; Waples et al., 2008).

- Flooding shapes the riverine system through geomorphological processes (e.g., erosion, sediment deposition and channel reformation) and is important for maintaining habitat diversity over longer time scales (Gordon et al., 2004). Large dams interfere with natural flooding processes (Gordon et al., 2004); however, dams can provide flood control benefits by reducing the impacts of flooding to downstream areas and minimizing downstream flood damages (Green et al., 2000). Dams with upstream flood control storage can also reduce the scouring of redds, or gravel-implanted salmon eggs, thereby increasing survival rates and salmon fry production (Miller, 1976). Levees are also constructed to protect property and increase human safety in floodplains (NRC, 1992). However, levees also alter environmental flows through increased velocities, narrow channels, and reduced floodplain connectedness (Ritter, 2006).

- Water withdrawals for human and livestock use also lead to flow impairment (Washington State Department of Ecology (Ecology), 1998; Poff et al., 1997; Postel and Richter 2003; Richter et al. 2003). The consumptive portion of the withdrawal varies depending on the type of water use and geographic area where the use occurs. *Indoor* water use in urban areas serviced by sewer in the Puget Sound area is 100% consumptive because the wastewater is typically not discharged locally. Consumptive water use in rural areas serviced by septic systems is significantly lower as wastewater is returned to the local groundwater system. Estimates of the consumptive portion of rural domestic use range from approximately 15 to 25% of total water use on an annual basis (U.S. Environmental Protection Agency (U.S. EPA), 1975; USGS, 1995; City of Sequim, 2002). Therefore, actual consumptive use varies significantly in rural versus urban environments.

In contrast, lower levels of hydrologic alteration are found in rivers located in large undeveloped areas where there are no mainstem dams (including Olympic National Park). This includes the following rivers: Sauk-Suiattle Rivers and Cascade River, Skykomish and Snoqualmie Rivers and upper Snohomish River, Deschutes River above Deschutes Falls, Kennedy Creek, South Fork Skokomish River above confluence with North Fork, Liliwaup Creek, Hamma Hamma River, Duckabush River, Dosewallips River, other east Olympic Hood Canal tributaries south of the Dosewallips, Lyre River, East Twin River, West Twin River, and Hoko River (Beecher, 2008).

Data Gaps and Uncertainties

As discussed above, there is no Puget Sound scale summary of freshwater resources. Much of what we know about the adequacy of water resources in Puget Sound has been assessed at a watershed scale by WRIA (water resource inventory area) or more locally. There are 19 WRIAs within the Puget Sound basin (Figure S1-2). Appendix A presents a summary of our knowledge about the adequacy of freshwater resources for both instream needs and out-of-stream benefits by WRIA and provides references for local studies[2].

However, even with local information, a regional estimate of ecological and human water needs is difficult due to:

- The disparity in water quantity data and its varying geographic distribution,
- Regional variation in climate and geology,
- The temporal and geographic variability in the needs of different species, and
- Institutional and political sensitivities associated with water use and instream flows.

[2] Material for this appendix was supplied primarily by the Department of Ecology and WDFW with input from other participants in watershed planning under RCW 90.82.

Graphics Source: Ruckelshaus and McClure, 2007. Annual freshwater inflows from Puget Sound Rivers are one of the major drivers of marine circulation patterns. Width of arrows indicates the average volume of annual freshwater flows to Puget Sound.

Figure S1-1
Annual Freshwater Inflows from Puget Sound Rivers

Gaging Station Name	Mean Annual Flow (cfs)	Period of Record (years)
Nooksack River at Ferndale	3,840	27
Samish River near Burlington	243	28
Skagit River near Mt. Vernon	16,600	53
N. F. Stillaguamish River at Arlington	1,890	65
Snohomish River near Monroe	9,540	30
Cedar River at Renton	666	48
Green River at Tukwila	1,490	27
Puyallup River at Puyallup	3,330	79
Nisqually River at McKenna	1,290	39
Deschutes River at Tumwater	330	6
Skokomish River near Potlatch	1,180	52
Dosewallips River near Brinnon	673	20
Dungeness River near Sequim	377	67

Data Source: Staubitz et al., 1997.

Appendix A: Summary of Freshwater Resource Adequacy

Puget Sound Partnership Action Area	WRIA	WRIA Name	Are Streamflow and Aquifer Levels Sufficient for:				**Are Streamflow and Aquifer Levels Sufficient for:** (Identify water use type e.g., municipal, industrial, agricultural, residential. Are these quantified?)				**Threats to Streamflows and Aquifer Levels** (e.g., water withdrawal, dam operations, etc.)	Data and/or Research	
			Fish and Wildlife (list species if applicable)	**Confidence Level (H, M, L)**	**Habitat (list habitat types)**	**Confidence Level (H, M, L)**	**Current Human Demands**	**Confidence Level (H, M, L)**	**Future Human Demands**	**Confidence Level (H, M, L)**	**Current and Future Threats:**	**Existing Data or Available Studies and References**	**Data Gaps and Research Needs**
San Juan/Whatcom	1	Nooksack	With few exceptions flows are not sufficient during the low flow period to provided maximum instream habitat for salmonids, including Chinook, Coho, Chum, Pink and Sockeye salmon, steelhead, cutthroat trout and bull trout/Dolly Varden. Lowland streams such as Bertrand subject to low flows through diversion and groundwater pumping, in combination with solar heating (lack of riparian shade) are sensitive to additional flow depletion and may benefit from flow restoration. Lower mainstem of the Nooksack River in late summer/early fall gets low enough that there has been suggestion of impairment of upstream migration near mouth due to combination of sediment deposition (shallow) and warming. Recommended salmon and steelhead rearing flows at the three reaches were 200, 560, and 570 cfs and he studied flows as low as 185, 342, and 585 cfs, respectively. In two out of three reaches more flow produced more rearing habitat in low flow season. Whatcom Creek may be an anomaly because water has been diverted into the lake and then some is removed, so not sure whether the creek has more or less flow than historically it had.		Diverse freshwater, estuary, wetlands, riparian. Instream Flow, wetted channel - Negotiations regarding degree to which flows meet habitat needs in process, as an implementation action under the WRIA 1 Watershed Plan		Because most drainages in WRIA 1 are closed to further surface water appropriation (and connected groundwaters) per WAC 173-501, or are limited by season or low flows, new water rights are not generally being issued in these basins at the current time. Further assessment is needed to make more detailed determinations of water availability for additional out-of-stream (or aquifer) uses. (M) Municipal demands are high, agricultural demands are high, shallow aquifers are replenished annually. Agricultural use depletes summer flows in lower basin tributaries, municipal use impacts Middle Fork Nooksack River. (H)	M-H	The degree to which human water demands can be met in the future is uncertain pending additional investigations into instream flow needs, growth projections and implementation of water management strategies, which must precede determinations of water availability for human needs.	M	**Current Threats:** Illegal water diversions; conversion of agricultural and forest land to residential or commercial development; cumulative impact of exempt wells; climate change. **Future Threats:** Growing demand for domestic and municipal water supply; conversion of forest and agricultural lands to subdivisions, commercial areas and industry; climate change	Utah State Univ. Decision Support System Model and supporting data; USGS and Ecology Flow and Water Quality Data, TMDLs. Much of documentation for flow limitation in Nooksack basin comes from instream flow studies using IFIM conducted by Brad Caldwell (Ecology mid-1980s) and Thom Hardy (Utah State University recently). These studies generally show that rearing habitat increases with increasing flow throughout the range of summer low flows, suggesting that the amount of flow limits the amount of rearing habitat. An exception may be rearing habitat for Coho salmon. The North Fork of the Nooksack River was one of the streams where Swift (1976, 1979) developed the toe-width method; in this study he determined suitable spawning and rearing flows for salmon by measurement of habitat at different flows. By comparing the flows that maximize habitat to gage data, it would be possible to ascertain that habitat is limited by low flows. • Salmon and Steelhead Habitat Limiting Factors in WRIA 1, The Nooksack Basin, Wash. State Conservation Comm. July 2002 • Nooksack Instream Resources Protection Program (WRIA 1), Chapter 173-501, Ecology, November 1985 • Bertrand Watershed Coordinated Irrigation District Management Plan, July 2004 • WRIA 1 Watershed Management Plan, Phase 1, Feb. 2005	Fish habitat needs in many reaches of WRIA 1 streams, hydrologic data in tributaries
San Juan/Whatcom	2	San Juan	Streamflow in Cascade Creek (Orcas) is listed as having low flow in the Salmon Habitat Limiting Factors Analysis produced by WA State Conservation Commission. Lower Cascade Creek - known to be inhabited by Coho and chum, sea-run cutthroat trout, juvenile Chinook salmon. Cascade Creek on the southeast corner of Orcas Island has a limited anadromous fish zone where some salmon spawn. It is heavily diverted and the subject of current discussions about trust water rights and flow restoration. A stream that flows into False Bay on San Juan Island may support salmon (Beecher has found none but there are reports in the old WDF stream catalog). It is part of the water supply for Friday Harbor and its flow is thus somewhat depleted. One other stream near Roche Harbor was reported by a now-retired WDFW		Very small lowland streams. Chinook known to use estuarine areas of other creek mouths on San Juans. Some local concern about reduction in flow of small streams that feed estuaries (but are not spawning/rearing areas).		Dependent on area of consideration - seawater intrusion has occurred mainly on San Juan and Lopez Islands. Some communities have turned to desalinization plants. Areas where bedrock geology is prominent have less stable water supplies - may run dry in summer. Water may be boated or trucked in. Rainwater collection is permitted by San Juan County building codes. .	M-L	Urban growth areas are Eastsound, Friday Harbor, Lopez Island. Eastsound Area water suppliers looking for additional sources to supplement water supply for predicted population growth.	M-L	**Current Threats:** Cumulative impact of exempt wells, potential contamination of aquifers, drought conditions, seawater intrusion. **Future Threats:** Growing demand for domestic and municipal water supply	see documentation and references. • Seawater Intrusion Report • Estimates of Ground-water Recharge from Precipitation to Glacial-Deposit and Bedrock Aquifers on Lopez, San Juan, Orcas, and Shaw Islands, San Juan County Washington (2002) • San Juan County Water Resource Mgmt Plan (Oct 2004) • WRIA 2 Phase II Basin Assessment (Aug 2002) • Multi-Purpose Water Storage Assessment (2004) • Salmon and Steelhead Habitat Limiting Factors Report for WRIA 2 (2002) • WDFW Report - Cascade Creek Fisheries (2007)	Aquifer flow model for the Eastsound Area, general groundwater monitoring (network being put in place in 2007), monitoring of seawater intrusion, effects of desalinization plants

Puget Sound Partnership Action Area	WRIA	WRIA Name	Are Streamflow and Aquifer Levels Sufficient for:				Are Streamflow and Aquifer Levels Sufficient for: (Identify water use type e.g., municipal, industrial, agricultural, residential. Are these quantified?)				Threats to Streamflows and Aquifer Levels (e.g., water withdrawal, dam operations, etc.)	Data and/or Research	
			Fish and Wildlife (list species if applicable)	Confidence Level (H, M, L)	Habitat (list habitat types)	Confidence Level (H, M, L)	Current Human Demands	Confidence Level (H, M, L)	Future Human Demands	Confidence Level (H, M, L)	Current and Future Threats:	Existing Data or Available Studies and References	Data Gaps and Research Needs
			habitat biologist (Art Stendal, Mount Vernon) to have a trout population, but when Brad Caldwell and Hal Beecher tried to verify this the stream was dry at its mouth. One stream on Lopez Island draining Hummel Lake to Port Stanley was a candidate for restoration of habitat for cutthroat trout, but it is unlikely any other salmonid might have used it. There are no instream flows in the Washington Administration Code (WAC) for this WRIA.										
Whidbey	3	Lower Skagit - Samish	Samish instream flow studies were performed for 5 targeted species- Chinook, Coho, Chum, Steelhead and cutthroat. The Samish River & Thomas Creek are on the SWSL list for flow impairments. Other flow impairments in the basin exist. Ecology is scheduled to develop and set an IRPP for the Samish basin. Other species present: Pink, Bulltrout, Sockeye. IFIM studies by John Blum and Pete Rittmueller (now with EES Consulting in Bellingham) in the Samish River suggest that low flows limit salmonid habitat. Samish River was one of the streams where Swift (1979) developed the toe-width method; in this study he determined suitable spawning and rearing flows for salmon by measurement of habitat at different flows. By comparing the flows that maximize habitat to gage data, it would be possible to ascertain that habitat is limited by low flows. Recommended salmon rearing flows at the three reaches were 25, 50, and 30 cfs and Swift studied flows as low as 12.6, 19.4, and 25.2 cfs, respectively. Thus low flows limited rearing habitat.		Diverse freshwater, wetlands, riparian, major estuary		Current municipal/commercial/domestic uses are being met through exempt wells & existing water rights. Ecology is not processing new water rights. Current irrigation needs may or may not be met by existing water rights, depending on the validity of water rights.	M-L	Irrigation needs may need additional water rights & supplies. Residential and Commercial generally will be met, except for some tributary areas not served by public water.	M-L	**Current Threats:** Water withdrawals, landscape changes. **Future Threats:** Climate change, growth, water withdrawals, landscape changes.	Draft Samish Watershed Plan, Skagit CIDMP, Chinook Recovery Plan. Samish Watershed Plan & Associated reports (instream flows, water use report), Skagit Chinook Recovery Plan, LFA, SWSL list. • Swift, 1979	Groundwater/ surface water interactions, Agricultural water needs (initial work done in CIDMP and watershed plan), divide between Skagit & Samish basins.
Whidbey	3&4	Lower Skagit/ Upper Skagit	The Skagit River is the only basin that still supports all six species of salmon. Also cutthroat and bulltrout. Yet, there are areas in the basin that are categorized as flow-limited by the Chinook recovery plan, the LFA & SWSL list.		Diverse freshwater, wetlands, riparian, major estuary. Flows have been modified in areas of the basin, including the Skagit Delta and estuary. 303(d) listings for temperature occur in the Lower Skagit		Muni-Domestic-Commercial- existing water rights, the water reservation and streamflows are generally adequate to meet water demands for 25-50 years in the future. However, in some tributary basins where public water doesn't exist could face water shortages in the near term. Ag uses- It is unknown to the degree existing water rights cover current irrigation needs. The Skagit CIDMP did a lot of work looking at current	M-L	Projections done under the instream flow estimate the water reservation & water rights generally meets water needs basin-wide for at least 25-50 years. The CIDMP identifies future water needs that will need new water rights that exceed the agricultural irrigation reservation.	M-L	**Current Threats:** Water withdrawals are limited under the instream flow rule but can still affect flows. Dam operations have been modified under FERC licenses to be more fish-friendly, but still impact flows. Landscape modifications- impervious surfaces, diking and draining, forest conversion threaten streams & aquifers. **Future Threats:** Growth, climate change, water withdrawals	LFA, Chinook Recovery Plan, Temperature TMDL for Lower Skagit, SWSL list, Skagit CIDMP. Mainstem instream flow studies for Anacortes and Skagit PUD by Michael Barclay (now with DTA in Bellingham) and John Blum and Pete Rittmueller (now with EES Consulting in Bellingham) in the Skagit River addressed estuarine flow-habitat relationships. The work was done in cooperation with Eric Beamer and others at the Skagit River Cooperative. It suggests that high flows contribute to rearing salmon (especially Chinook) access to estuarine flats and reduction in those high flows would reduce their access to those feeding areas. They also studied a number of different tributaries to the lower Skagit in the Cultus Mountain area for the PUD; these studies suggested that habitat was limited by low flow. In their lower mainstem work and in other mainstem work farther upstream below the Baker River confluence by Phil Hilgert (R2 Resources Consultants, Redmond) habitat was not very sensitive to flow in this big river, except that connections to lateral habitats (side channels, sloughs), which can be very important for juvenile salmon production, varied with flows. An important factor for fish production is flow fluctuation and ramping rate in a regulated river such as the mainstem Skagit. Connor and Pflug (2004) documented improved production of several salmon in the upper mainstem Skagit below Seattle City Light's project in response to SCL's management of flow fluctuation to stabilize incubation and rearing flows and minimize stranding of redds and fry. Their results suggest that the regulated upper Skagit is not only more	Groundwater/ surface water interactions (current study being done by USGS), Basin-wide Water Supply Planning.

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			Fish and Wildlife (list species if applicable)	**Confidence Level (H, M, L)**	**Habitat (list habitat types)**	**Confidence Level (H, M, L)**	**Current Human Demands**	**Confidence Level (H, M, L)**	**Future Human Demands**	**Confidence Level (H, M, L)**	**Current and Future Threats:**	**Existing Data or Available Studies and References**	**Data Gaps and Research Needs**
					tributaries.		& future irrigation water use in WRIA 3.					favorable for salmonid production now than it was, but more favorable than other nearby rivers.	
Whidbey	5	Stillaguamish	Chinook, Coho, pink, chum, steelhead, cutthroat, bulltrout. LFA lists WRIA 5 as impaired by flows WRIA-wide. Ecology adopted IRPP in 2005 for the Stillaguamish basin. Recommended salmon and steelhead rearing flows at the three reaches were 110, 150, and 200 cfs and he studied flows as low as 15, 14, and 203 cfs, respectively. Clearly, low flows strongly limit rearing habitat at these reaches.		Diverse freshwater, wetlands, riparian, major estuary		Current human demands met through existing water rights and exempt wells in rural areas. No watershed planning was done to determine adequacy of existing supplies to meet current demand.		No watershed planning was done in WRIA 5- uncertain if public water suppliers face future shortfalls. IRPP reservation covers domestic exempt wells & stockwater uses up to 5 cfs. Agricultural irrigation appears to be declining in the basin.		**Current Threats:** Water withdrawals, landscape changes. **Future Threats:** Growth, climate change, water withdrawals	State of Stillaguamish report, LFA, WAC 173-505, Stillaguamish Chinook Recovery Plan. Sandra Embrey (USGS, Tacoma) conducted a series of IFIM studies for the Stillaguamish Tribe in the 1980s. In general, her results also suggested that flow limits habitat because more flow resulted in higher habitat index (WUA) within the range of low flows normally encountered. The North Fork of the Stillaguamish River was one of the streams where Swift (1976, 1979) developed the toe-width method; in this study he determined suitable spawning and rearing flows for salmon by measurement of habitat at different flows. By comparing the flows that maximize habitat to gage data, it would be possible to ascertain that habitat is limited by low flows. State of Stillaguamish report, LFA, WAC 173-505, Stillaguamish Chinook Recovery Plan.	Ground-surface water interaction, current & future water use and demands
Whidbey	6	Island	Chum, Coho, cutthroat. Unknown-no studies done under watershed planning & many stock status are unknown. Limited information available in LFA. Salmon streams are few and small on Whidbey Island. Steve Boessow (WDFW Habitat Program, Water Rights Biologist) evaluated at least one salmon-bearing stream and concluded that flow was probably a limiting factor and additional water withdrawal would be detrimental to fish habitat. There are no instream flows in the Washington Administration Code (WAC) for this WRIA.	L	Very small lowland streams. Unknown how & if salmon use freshwater resources or just marine habitats.	L	Parts of WRIA 6 experience seawater intrusion. Other areas appear to have adequate freshwater supplies. Almost all human water use is from groundwater. Ecology is currently processing new water rights in WRIA 6.	M	Some parts of WRIA 6 may not have enough water supply for future growth. Other parts of WRIA 6 appear to have adequate water supplies.	M	**Current Threats:** Water withdrawals, seawater intrusion, loss of native landscape lowering recharge. **Future Threats:** Growth/water withdrawals, climate change, loss of native landscape and recharge capacity of the land.	Island County Water Resource Management Plan, USGS Island County Study, Salmon Recovery Plan.	Freshwater use by fish. Freshwater needs of near-shore areas. Recharge areas.
Whidbey	7	Snohomish	Chinook, Coho, pink chum, steelhead, cutthroat, bulltrout. Salmon Plan & LFA lists flows as a limiting factor in parts of WRIA 7. Instream flow frequently not met. Recommended salmon rearing flows at the three reaches were 1200, 860, and 2800 cfs and he studied flows as low as 624, 934, and 2200 cfs, respectively. At these relatively large, mainstem river site, low flow limits rearing habitat.	M	diverse freshwater, wetlands, riparian, major estuary		Everett & KC communities participate in regional water supply planning. Unknown if current human demands are being met elsewhere.	?	Everett & KC communities participate in regional water supply planning. Demands met until 2060. No watershed planning has been done to determine if future demands will be met. IRPP limits development of new water rights.	?	**Current Threats:** Water withdrawals, loss of native landscape, climate change. **Future Threats:** Growth, water withdrawals, climate change, land cover loss & impervious surfaces		Enhance documentation of flow problems, modeling flows/salmon survival & productivity, SHIRAZ/EDT model changes related to flow, evaluate land use/land cover & runoff impacts, address socio-economic concerns

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			Fish and Wildlife (list species if applicable)	Confidence Level (H, M, L)	Habitat (list habitat types)	Confidence Level (H, M, L)	Current Human Demands	Confidence Level (H, M, L)	Future Human Demands	Confidence Level (H, M, L)	Current and Future Threats:	Existing Data or Available Studies and References	Data Gaps and Research Needs
South-Central Puget Sound	8	Cedar-Sammamish	No- for Sammamish River (chinook, steellhead, coho ,sockeye), Cedar River (chinook, steelhead, sockeye), Issaquah Cr (chinook, coho, sockeye, steelhead), Bear Cr (chinook, coho, sockeye, steelhead), Rock Cr (chinook, steellhead, sockeye). Also bulltrout, cutthroat, pink. Instream flows frequently not met. Recommended steelhead and salmon rearing flows at the three reaches were 5, 7, and 8 cfs and he studied flows as low as 4.8, 5.4, and 7.4 cfs, respectively, in Bear Creek; they were 25, 35, and 40 cfs and he studied flows as low as 27, 37, and 57 cfs, respectively, in Issaquah Creek; they were 75, 90, and 80 (revised to 150, Swift 1976) cfs and he studied flows as low as 76, 89, and 200 cfs, respectively, in the Cedar River. In Bear Creek low flows limit rearing habitat, in Issaquah Creek and the Cedar River low flows showed no clear evidence of limiting rearing habitat.	M	Lake, low to mid elevation streams of small to medium size, wetlands and riparian						**Current Threats:** Sammamish River-domestic development (closed by rule), Cedar River-municipal and domestic development(minimum instream flows set by rule), Issaquah Cr-domestic development (closed by rule), Bear Cr (closed by rule) Rock Cr- development (closed by rule)		
South-Central Puget Sound	9	Duwamish-Green	Chinook, coho, steelhead, cutthroat. No-Green River, Newaukum Creek, Soos Cr. Instream flow frequently not met. Recommended steelhead and salmon rearing flows at the three reaches were 200, 250, and 250 cfs and he studied flows as low as 188, 232, and 225 cfs, respectively. Low flow limited rearing habitat.	M	Lake, low to mid elevation streams of small to medium size, wetlands and riparian						**Current Threats:** Green River- municipal diversion(minimum instream flows set by rule),Newaukum Creek -Dairy diversions(closed by rule) , Soos Cr-domestic development(closed by rule)	Bear Creek, Issaquah Creek, and the Cedar River were streams where Swift (1976, 1979) developed the toe-width method; in this study he determined suitable spawning and rearing flows for salmon and steelhead by measurement of habitat at different flows. By comparing the flows that maximize habitat to gage data, it would be possible to ascertain that habitat is limited by low flows. Brad Caldwell (1989) conducted IFIM studies on the Green River and his results suggested that low flows limit fish habitat. His results were similar to Swift's. April 2, 1999 Ecology response to Legislature on Flow Impaired Streams with Significant Diversions	
South-Central Puget Sound	10	Puyallup-White	Chinook, coho, pink, chum, steelhead, cutthroat, bulltrout. Maybe-Puyallup River, White River. Recommended steelhead and salmon rearing flows at the three reaches were 80, 100, and 100 cfs and he studied flows as low as 35, 39, and 55 cfs, respectively. Low flow limited rearing habitat.	M	Diverse freshwater, wetlands, riparian						**Current Threats:** Puyallup River - hydroelectric project but large recent improvement (minimum instream flows set), White River-hydroelectric project now gone and flows restored for last 4 years and last 2 years spring chinook run restored to thousands(closed by rule)	South Prairie Creek was a stream where Swift (1976, 1979) developed the toe-width method; in this study he determined suitable spawning and rearing flows for salmon and steelhead by measurement of habitat at different flows. By comparing the flows that maximize habitat to gage data, it would be possible to ascertain that habitat is limited by low flows. Instream flow studies using IFIM were conducted in the 1980s by Phil Hilgert for Puget Sound Energy in the White River bypass reach for the hydroelectric project. Subsequent restoration of much of the flow to the bypass reach has led to significant increases in salmon use of the 23-mile bypass reach. April 2, 1999 Ecology response to Legislature on Flow Impaired Streams with Significant Diversions	

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South Puget Sound	11	Nisqually	Summer flows are "of concern" to meet the needs of Nisqually River (NR) Fall Chinook (threatened); NR Winter Chum; NRr Coho; (candidate); NR Pink; NR Winter Steelhead; NR Sockeye; NR Bull Trout (threatened); NR Coastal Cutthroat.		Diverse freshwater, wetlands, riparian, major estuary		Municipal supply problem exist now, and allocations generally exceed both summer and winter supply, with July-Sept "points of concern". McAllister Creek is closed to further withdrawals. Aquifers appear to be depleting throughout the WS, with rates ranging from high (McAllister) to low (most others).				**Current Threats:** Growth, including increased water demands and water quality degradation; there are 18 dams in the WS. **Future Threats**: Growth, including increased water demands and water quality degradation;	Level 1 WS Assessment; Nisqually Chinook Recovery Plan 2001; Nisqually River Basin Plan Characterization Report 2006; Assessment of Surface Water and Groundwater Interchange within the Muck Creek WS Pierce County 2001; Flow Investigation of the Nisqually River Lower Reach Thurston County, WA 2001. Instream flow studies in 1979-80 by John Easterbrooks (Washington Department of Fisheries, now at WDFW, Yakima office) were used to regulate instream flow releases at the Yelm hydroelectric project and subsequent studies were used to determine flow release requirements at LaGrande Dam. The watershed planning unit commissioned an IFIM study by Golder on the Mashel River, but study is not complete.	Evaluation of various hydrologic impacts of development; estimation of natural streamflows; extent of actual irrigation; additional groundwater modeling; additional gaging; verification of WR claims; evaluate WR usage; correct WRATS;
South Puget Sound	12	Chambers-Clover	Chinook, coho, chum, steelhead, cutthroat. No-Sequalitchew Cr	M	Low elevation streams, lakes, riparian and wetlands						**Current Threats:** Sequalitchew Cr-municipal, floodway relief (closed by rule)	No instream flow studies have been conducted, but upper reaches of the watershed were found to be intermittent during review of water right applications in the 1990s by Hal Beecher (WDFW). It is one of the original 16 critical water limited basins (as determined by professional opinion of Ecology staff).	
South Puget Sound	13	Deschutes	Chinook, coho, chum, steelhead, cutthroat. Recommended steelhead and salmon rearing flows at the three reaches were 40, 60, and 70 cfs and he studied flows as low as 22, 26, and 68 cfs, respectively. Low flows limit rearing habitat. Woodland Creek is dry in the vicinity of the Ecology headquarters below Lake Lois in most summers. There is a lot of growth pressure and groundwater withdrawal in this area.		Lake, low to mid elevation streams of small to medium size, wetlands and riparian						**Current Threats:** Growth pressure and groundwater withdrawal	The Deschutes River was a stream where Swift (1976, 1979) developed the toe-width method; in this study he determined suitable spawning and rearing flows for salmon and steelhead by measurement of habitat at different flows. By comparing the flows that maximize habitat to gage data, it would be possible to ascertain that habitat is limited by low flows.	
South Puget Sound	14	Kennedy-Goldsborough	Chinook, coho, chum, steelhead, cutthroat. Limited by low flow.		l\Lake, small low elevation streams, wetlands and riparian, estuary							Ken Slattery (Ecology) conducted an IFIM study of Goldsborough Creek in the 1980s and results suggested rearing habitat is limited by low flow. Kennedy Creek has been the subject of considerable study, but instream flow studies have not been part of the studies.	
South Puget Sound and Hood Canal and South Central Sound	15	Kitsap	Chinook, coho, chum, steelhead, cutthroat. Many basins closed to further allocation - instream flow rules under WAC 173-515-040. See also: Salmonid Habitat Limiting Factors WRIA 15 (Kitsap). A number of streams seasonally or fully closed to water allocation. Recommended salmon rearing flows at three reaches on the Dewatto River were 20, 20, and 40 cfs. Low flows limit rearing habitat on the Dewatto River. Low flow		Lake, small low elevation streams, wetlands and riparian, estuary. Numerous low-elevation, low-gradient streams. 125 separate streams supporting salmonids. Highly productive		Kitsap County relies heavily on groundwater supplies. Concern about recharge rates and sustainability of aquifers throughout basin. Many closed streams from instream flow rules set in the 1980s. See WAC 173-515-040. Much effort being put towards study of reclaimed water opportunities.		Concern about recharge rates of aquifers. Reclaimed water being considered to help provide for future secondary uses.		**Current Threats:** Cumulative impact of exempt wells, stormwater runoff, flashy streamflows, drought conditions. **Future Threats:** Population growth, development; Retention of natural stream hydrology imperative. Drawdown of aquifers that support streamflow through hydraulic continuity	see documentation and references. The Dewatto River was a stream where Swift (1979) developed the toe-width method; in this study he determined suitable spawning and rearing flows for salmon by measurement of habitat at different flows. By comparing the flows that maximize habitat to gage data, it would be possible to ascertain that habitat is limited by low flows. The WDFW Water Team conducted instream flow study using IFIM (http://wdfw.wa.gov/hab/science/papers/barkercrk_instreamflow.pdf) in Barker Creek near Silverdale. This study indicated that low flow limits habitat in Barker Creek. Big Beef Creek is one of the more intensively studied streams, but instream flow studies have not been a direct focus of the studies. Big Beef Creek is one of several streams in the area being studied as part of the Intensively Monitored Watersheds by WDFW and Ecology, in which flows and fish production are being monitored. • Kitsap Instream Resources Protection Program (WRIA 15), Chapter 173-515, Ecology • WRIA 15 - Instream Flow Assessment Step C Report • Barker Creek Rainwater Study • Site Screening/Selection Report - Kitsap Stormwater Infiltration Project	Economic viability of reclaimed water use, aquifer modeling, impact of wells on instream flows, viability of aquifer storage, infiltration galleries

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			Fish and Wildlife (list species if applicable)	Confidence Level (H, M, L)	Habitat (list habitat types)	Confidence Level (H, M, L)	Current Human Demands	Confidence Level (H, M, L)	Future Human Demands	Confidence Level (H, M, L)	Current and Future Threats:	Existing Data or Available Studies and References	Data Gaps and Research Needs
			limits habitat in Barker Creek.		for chum, coho, cutthroat. Many streams do not have year round surface flow.							• Karcher Creek - Reclaimed Water Production and Distribution Report • Kitsap County WISER Water Summary Report • Kitsap County - Reclaimed Water Quality - Regulatory and Permitting Considerations • Kingston Reclaimed Water Report • Salmonid Habitat Limiting Factors WRIA 15 (Kitsap) and WRIA 14 (Kennedy Goldsborough Basin) • WRIA 15 Watershed Plan (not approved)	
Hood Canal	16	Skokomish - Dosewallips	Chinook, coho, chum, pink, steelhead, cutthroat, bulltrout. Low summer flows impact the Hood Canal Summer Chum runs, currently a listed species. Aspect 2005 Instream flow study focused on fish passage flows in drought year. Recommended salmon rearing flows at the three reaches were 180, 300, and 220 cfs and he studied flows as low as 131, 128, and 129 cfs, respectively. Low flows limit rearing habitat.	M	Diverse freshwater, wetlands, riparian, major estuary. Passage for summer chum, fall chum, coho, pink, steelhead, chinook	M	Streamflows are generally adequate for most water uses, although there is currently not a great demand. Low summer flows are exacerbated by agriculture in the Skokomish valley. Municipal, residential, hydro (Skokomish), limited agriculture.	M	Population growth along the shoreline of Hood Canal will present significant potential stress on available supplies through existing municipal water suppliers. Future exempt well usage may have a significant impact on summer streamflows. Municipal, residential.	M	**Current Threats:** Cushman dam diversion. No limitations on permit exempt wells. Forest practices, land use, dam operation (Skokomish), gw withdrawals. **Future Threats:** Limited new water rights will be issued. Climate change, land use, seawater intrusion	Level 1 Technical Assessment. Brinnon area groundwater study. Yes, for water use estimates, very limited flow data, limited gw/sw interaction data, limited gw characterization studies. The Dosewallips River was a stream where Swift (1976, 1979) developed the toe-width method; in this study he determined suitable spawning and rearing flows for steelhead and salmon by measurement of habitat at different flows. By comparing the flows that maximize habitat to gage data, it would be possible to ascertain that habitat is limited by low flows. Brad Caldwell (Ecology) has conducted IFIM instream flow studies on several of the rivers in this watershed: Jorsted, Fulton, Dosewallips, Hamma Hamma, John, Duckabush, NF and SF Skokomish. In addition, Hal Beecher (Game) proposed instream flows by letter of March 22, 1985 for these as well as other streams where toe width had been done. Several IFIM studies were conducted for proposed hydroelectric projects in the 1980s: Hamma Hamma by Forrest Olson (CH2M Hill, Bellevue), Dosewallips by Phil Hilgert (now with R2 Resources, Redmond). These studies all indicated that low flows limit fish habitat. The Dosewallips study was a key piece of evidence in the Pollution Control Hearings Board appeal of the Water Quality Certification instream flow conditions; this case went the State Supreme Court and the U.S. Supreme Court, affirming Ecology authority to set instream flows under the Clean Water Act. There are no instream flows in the Washington Administration Code (WAC) for any streams in this WRIA. This makes the basin more susceptible to withdrawals that could exacerbate low flows. Hydrogeologic study of lower Dosewallips/Brinnon Area, Aspect Consulting, 2005; WRIA 16 Instream Flow Studies, Jefferson and Mason Counties, WA Aspect Consulting, 2005; WRIA 16 Technical Assessment, USGS Estimates of nitrogen loading and groundwater discharge to Hood Cana, pending 2009	Verification of hundreds of water right claims. Tracking existing water right usage. Unknown illegal water use. Limited groundwater level monitoring. Only partial streamflow gaging. Long term trends, Verification of initial findings in Aspect instream flow study requires more time/flow data
Hood Canal and Strait of Juan De Fuca	17	Quilcene-Snow	Chinook, coho, chum, pink, steelhead, cutthroat. Low summer flows impact the Hood Canal Summer Chum runs, currently a listed species, in particular in Big Quilcene, Chimacum Creek	M	Diverse freshwater, wetlands, riparian, major estuary	M	Streamflows are generally to the point that, while adequate for most existing water uses, future appropriations of water are problematic. Low summer flows are exacerbated by agriculture in the Chimacum valley. Industrial (paper mill), municipal, agriculture (Chimacum Valley), residential	H	Population growth along the shorelines will present significant stress on available supplies through existing municipal water suppliers. Future exempt well usage may have a significant impact on summer streamflows. Municipal, residential, agriculture and industrial uncertain	M	**Current Threats:** No limits on permit exempt wells. Population growth, forest practices, land use, gw withdrawal impacts to streams, sea water intrusion. **Future Threats:** Very limited new water rights will be issued. Restrictions may be imposed on all future groundwater withdrawals (including exempt wells). Climate charge, forest practices, land use, gw withdrawals, sea water intrusion	Level 1 Technical Assessment. WRIA 17 Detailed Implementation Plan. USGS Chimacum Groundwater Study. Limited groundwater characterization, some gw/sw interaction studies, unpublished instream flow work (WDFW). Brad Caldwell (1999) conducted an IFIM study in the Quilcene River in the 1980s and Hal Beecher (WDFW) evaluated summer chum salmon spawning and incubation habitat as a function of flow using a wetted width approach in the lower Quilcene. These results indicated that low flow limits fish habitat in the Quilcene. The Quilcene River is the water supply for Port Townsend and the mill. Beginning in 1979, Hal Beecher (WDFW) conducted an IFIM study in Snow Creek but the study was not completed until 2004. Terra Hegy (2005; http://wdfw.wa.gov/hab/science/papers/quill_snow_watershed.pdf) completed a wetted width study that showed habitat is limited by flow in many streams in the watershed. There are no instream flows in the Washington Administration Code (WAC) for this WRIA although a rule is in progress. Ground-Water System in the Chimacum Creek Basin and Surface Water/Ground Water Interaction in Chimacum and Tarboo Creeks and the Big and Little Quilcene Rivers, Eastern Jefferson County, Washington, USGS, 2004; WRIA 17 Technical Assessment, Parametrix, 2000; USGS Groundwater Model Chimacum Valley, pending 2009	Verification of hundreds of water right claims. Unknown illegal water use. Limited groundwater level monitoring. Only partial streamflow gaging. Long term trends for sw/gw; hydrogeologic characterization of Quilcene-Dabob Bay area; precipitation coverage.

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			Fish and Wildlife (list species if applicable)	Confidence Level (H, M, L)	Habitat (list habitat types)	Confidence Level (H, M, L)	Current Human Demands	Confidence Level (H, M, L)	Future Human Demands	Confidence Level (H, M, L)	Current and Future Threats:	Existing Data or Available Studies and References	Data Gaps and Research Needs
Strait of Juan De Fuca	**18**	Elwha-Dungeness	Chinook, coho, chum, pink, steelhead, cutthroat, bulltrout. No- Dungeness River, Little Quilcene River, Chimacum Cr. Flows limit fish habitat.	M	diverse freshwater, wetlands, riparian, major estuary						**Current Threats:** Dungeness- Irrigation, municipal, domestic development diversions (no instream flows set by rule), Little Quilcene River- Irrigation, municipal, domestic development diversions (no instream flows set by rule), Chimacum Cr- Irrigation, municipal, domestic development diversions (no instream flows set by rule).	An instream flow study of the Dungeness River using IFIM was conducted by Phil Wampler and Joe Hiss (1999). This study indicated that rearing habitat is limited by low flows. Jonathan Kohr (WDFW, Yakima) is evaluating flow restoration and is documenting low flows limiting upstream migration of spawning salmon in the late summer and early fall in the Dungeness River. The Dungeness flow protection and restoration efforts are discussed in a chapter in Locke et al. (2008, in press), including discussions of negotiations as well as technical details. Morse Creek has been the subject of an instream flow study using IFIM by Ken Slattery (Ecology) in the 1980s and validation of some of the assumptions in IFIM by Beecher et al. (1993, 1995, 1997). Slattery's studies indicated that flow limits fish habitat. There are no instream flows in the Washington Administration Code (WAC) for this WRIA although a rule is in progress. Dungeness- Irrigation, municipal, domestic development diversions (no instream flows set by rule), WRIA 18 Technical Assessment	
Strait of Juan De Fuca	**19**	Lyre-Hoko	Chinook, coho, chum, pink, steelhead, cutthroat, bulltrout. No- but these rain fed naturally go very low - there are few diversions		lake, mid to low elevation streams, riparian and wetlands							Flows get so low early in the summer and late in the spring that downstream migrants are sometimes trapped behind the beach, based on observations of residents who corresponded with Terra Hegy (WDFW). John Blum (EES Consulting, Bellingham) conducted a modified IFIM study in some of these streams and his results also suggest that flow limits habitat. Toe width data were collected by Terra Hegy (WDFW) and Jim Pacheco (Ecology) and then developed into instream flow recommendations which show streams flow limited when comparing ideal habitat flows and actual flows. There are no instream flows in the Washington Administration Code (WAC) for this WRIA although a rule is in progress.	

Appendix A Matrix References

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